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Characterization of the Pulpwood Procurement Environment of Northwest Louisiana With a Geographic Information System.

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Characterization of the pulpwood procurement environment of northwest Louisiana with a geographic information system

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CHARACTERIZATION OF THE PULPWOOD PROCUREMENT ENVIRONMENT OF NORTHWEST LOUISIANA WITH A GEOGRAPHIC INFORMATION SYSTEM

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in Partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The School of
Forestry, Wildlife, and Fisheries

by
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ABSTRACT

An analysis of the pulpwood procurement environment was made to describe and model forest land area, ownership patterns, timber production, forest inventory, and the transportation network of 13 parishes in the northwest region of Louisiana.

Pulpwood delivered to a pulpmill accounts for approximately 50 percent of pulp production costs. The cost of delivered pulpwood is a function of the mode of transportation, distance from the mill, competition for stumpage, and quality of the transportation network. A data base is developed from wood usage requirements, pulpmill and wood concentration yard locations, location of forested areas and their relative volumes. Areas of potential sources of pulpwood stumpage were developed via procurement zones around each of the wood procurement centers in this region.

Three major problems addressed in this study were 1) the effects of zone overlap and wood supply percentage at various delivery points, 2) locations of competitively void areas that would support future wood yards, and 3) relocations of wood concentration yards. Output of the analysis was in the form of maps and descriptive statistics from the GIS database. Various scenarios were modeled by manipulating relocations of woodyards from areas of high competition to areas of lesser competition.

INTRODUCTION

Wood procurement is a specialization in forestry that has received minimal research attention in the past. A large percentage of all industrial forestry graduates are employed in wood procurement, yet little effort is expended on research to analyze and improve wood procurement techniques. Probably no other specialization within forestry has such an immediate financial impact as wood procurement. Effects of decisions made by the wood procurement forester today are revealed in days and weeks, and not in the years and decades imposed by biological and silvicultural decisions.

Wood procurement encompasses a broad area for which there is no succinct definition. Generally stated, it is the art and science of accomplishing all activities related to the purchase and securing of wood fiber resources for resale or re-manufacture (Brinker and Jackson 1987). The procurement forester's main objective is to minimize the delivered cost of wood to a mill or intermediate concentration yard. To attain this objective, the wood procurement forester must be aware of the three major components that comprise the delivered wood cost: 1) stumpage price, 2) harvesting cost, and 3) transportation cost. These factors form a volatile component of processing costs in the forest products industry. The wood procurement task is complicated by the fact that competition for stumpage dictates the timber selling price, and transportation costs are affected by the distance from woods to the delivery point and by the quality of the existing road network over which the wood is transported.

One of the basic problems confronting the wood procurement forester is where to begin the search for wood fiber. On a micro-scale the forester on the ground usually approaches this problem by applying the "art" portion of the above definition. The use of this approach involves the time consuming task of acquiring wood procurement knowledge through experience in the field. The wood procurement forester has to learn 1) the geographic area, 2) who has timber for sale or might be convinced to sell, 3) what the costs are to harvest and transport the timber, 4) the types and lengths of contracts to negotiate, and 5) the maximum affordable delivered prices allowed for timber. The wood procurement forester must also be able to visualize and react to any unforeseen event that may affect the ability to purchase timber. Wood procurement information is acquired through personal contacts with landowners, loggers, and consulting foresters and is based on the credibility established over time by the individual and the wood procurement organization.

On a macro-scale, the approach to the search for wood fiber is centered around determining the availability of wood fiber on a regional basis and evaluating the effects of competition within a proposed procurement region. Data for this approach are usually obtained from USDA Forest Service resource bulletins, wood-using industry directories, and independent marketing surveys of wood availability. The macro approach usually involves interviews with pulpwood dealers, pulpmill procurement personnel, consulting foresters, state forestry personnel, and others. The competition for the resource is usually described in terms of average procurement radii and estimated wood requirements of competitors; the wood fiber resource itself is usually described in terms of volumes of growing stock available and annual harvest volumes tabulated on as small a geographic area as possible. Output from this approach is normally in the form of statistical tables and thematic maps that portray the information in a georeferenced format.

The role that wood procurement has in forest operations in the southern United States is heavily weighted by the relative amounts of land owned by the forest industry, and by the non-industrial private forest (NIPF) landowner. In the midsouth, NIPF landowners control 66 percent of the total timberland acreage (Birdsey and McWilliams 1986). The majority of timber harvested from these NIPF lands will probably be secured through the efforts of procurement foresters.

In addition, approximately two-fifths of the nation's timberland is in the South (USDA Forest Service 1982). This area presently produces nearly one-half of the wood used in the pulp industry, in addition to one-third of the lumber and two-fifths of the plywood. Most of the expansion in the timber processing industry in the United States is expected to come from this geographic area over the next 3 decades (USDA Forest Service 1982).

By the year 2030 lumber processing capacity is only expected to have increased by 6 percent; whereas, pulp processing capacity is expected to have increased by 134 percent (Haynes and Adams 1981). The bases for the optimistic pulp processing projection are the favorable growing conditions and processing profitability in the South.

The commercial timberland base of Louisiana covers 45.4 percent of the state's 12.4 million hectare (30.6 million acre) land mass. Timberland ownership includes government (9.6 percent), industrial (30.8 percent), and non-industrial, private (59.6 percent) (May and Bertelson 1986).

In 1982, the forest industry accounted for over 61 percent of the total value added by the agriculture industry to the Louisiana economy (U.S. Dept. of Commerce, Bureau of the Census 1982). Louisiana is a source of raw material for 223 wood using plants, of which 13 are pulpmills requiring over 8.4 million cunits (100 cubic feet) of wood annually. In addition to the final mill delivery points, over 100 pulpwood concentration yards are located throughout the state (King and Nachod 1981).

Previous studies of wood procurement have included 1) descriptive analyses of raw material location, conversion mill locations and raw material requirements, 2) economic analysis of timber inventories, 3) supply and demand projections, and 4) allocation strategies of harvesting systems and inventories using mathematical programming techniques. A technique that has potential applicability and is being explored in this study is the use of geographic information systems (GIS) to facilitate better wood procurement practices with respect to wood resource location.

Historically, foresters are trained to handle tables of statistics, and the use of maps to process spatial information has been a forester's tool for many years. For basic wood procurement decision-making, the location of specific quantities of timber by specific categories must be known. This requires creation of a database and the production and use of maps. When the database and maps are stored, updated, and manipulated within a computerized system, the essentials of a computerized GIS are present. With GIS, the technology is available to efficiently present this wealth of information in a convenient manner. Selective information retrieval, ease of editing and updating the database, and output of combinations of database entities in tabular and spatially referenced map form can be accomplished with a GIS (Berry 1978).

The principle objective of this project was to develop a spatial pulpwood procurement model of the pulpwood procurement zones in the northwest region of Louisiana, from data entered into a GIS. Specifically the objectives are to

1. describe and model the forest land area, ownership, transportation network, pulpwood production and forest inventory of the northwest region of Louisiana,
2. characterize all pulpwood purchasers in the selected region by resource purchased, type of facility, transportation modes used for inbound wood shipments, and to define relevant factors influencing timber purchase decisions; and to develop a database of pulpwood purchases of pulpmills and wood concentration yards located in the northwest region of Louisiana, and
3. determine the potential capacity of the regional pulpwood market and develop a method to simulate a restructure of the spatial competition of the regional pulpwood market.

REVIEW OF LITERATURE

Forest Resource Decision Making

The use of GIS in evaluating existing resource development opportunities in the arena of pulpwood conversion and wood procurement analysis has been virtually nonexistent. In an approach of this nature, one must consider a variety of factors for inclusion in the analytical procedure.

A primary consideration in most approaches to this type of evaluation is an analysis of the wood supply. Wood supply is often indicative of wood costs, and wood costs are an important factor in the operating costs of the pulp industry (Hagenstein 1962). Wood supply information is readily acquired from USDA Forest Service resource bulletins.

Clawson (1977) suggested that it may be more enlightening to approach wood supply analysis from a "willingness to harvest" perspective rather than a total "timber supply." He evaluates "willingness to harvest" based on broad ownership classes and characteristics of these owners. Small private landowners generally harvest on a purely economic basis and tend to keep investment costs as low as possible. Vertically integrated industrial forest firms generally own 50 percent of their wood supply and harvest on a combination of biological and economic factors (Clawson 1977). National forests are without processing facilities and are dependent on at least one buyer for timber sales administration. Clawson stated that ownership characterization should be included in any evaluation of wood procurement and timber supply development.

In a recent study in the South, regional differences in pulpwood prices were evaluated (Hunter 1982). In this analysis, stumpage prices were found to be related to variations in regional characteristics. The significant characteristics found to affect pulpwood stumpage prices were price of pulpwood f.o.b. railcar, average pulping capacity within 100 miles, regional wood specific gravity, rural population density, and percentage of small landowners (less than 220 acres). That these factors are significant in every region is not necessarily true, but the relative importance of these factors as affecting pulpwood stumpage prices can be grasped intuitively.

The locations of pulping facilities and solid wood products plants have been the subject of numerous unpublished industrial studies and have been evaluated by forest researchers (Hagenstein 1962, Gardner 1966, Dane 1970, Holley 1970, O'Laughlin and Cleaves 1986). The more important economic factors affecting the geographical location of wood conversion facilities are cited in these studies as being: 1) labor cost and availability, 2) available stumpage, and 3) transportation cost and availability. The relative importance of these three factors will vary between and within geographic regions. Companies that purchase wood and are contemplating expansion to a different geographic area must be aware of the relative importance of these factors and acquire the capability to analyze the specific areas under consideration to support a facility location change.

USDA Forest Service resource surveys generally characterize regional inventories by volume, species, and ownership, but little attention is usually given to harvest and transportation costs. To estimate the full potential of a forest region requires an integrated, strategic, and economic estimate (Bradley and Winsauer 1978). This evaluation should include regional inventories by stand condition, regional guides of recommended harvesting practices, and simulator based estimates of harvesting costs. This type of analysis has been done for northern Wisconsin and Michigan by Bradley and Winsauer (1978), in a study where average delivered cost curves were constructed, and supply curves were developed for combinations of forest types, harvest methods, and residue components.

A study similar with respect to harvesting systems analysis was conducted in Maine, but was developed using a GIS approach (Reisinger and Davis 1985). This GIS was developed on an Intergraph minicomputer system, with the study area being a 56,680 hectare (14,000 acre) forest in northern Maine. Stand types, topography, soils, and available harvesting systems were analyzed. This approach allowed the forest owners to evaluate operable areas for harvesting and to determine the required type of harvesting system for a specific soils and timber combination; thus an indication of future relative harvesting costs on the forest based on current harvesting system costs could be obtained.

Forest resource decision making is not entirely objective. Subjective elements that by their nature cannot be easily quantified must be considered; but, these two approaches, objective and subjective, differ in data requirements and analytical techniques. An approach to combine the two forms of analysis by using the descriptive capabilities of simulation modeling in tandem with the prescriptive capabilities of graphical evaluation techniques was demonstrated by Hall (1981). This was an iterative approach in which the author described a forest development forecasting system for specific resource descriptions and management options on a hypothetical 100,000 hectare forest. This forest was assumed to be homogenous with respect to site and forest cover, and was described on the basis of tree size and volume by area. Forest harvesting options were limited to clear-cutting, with a management option to consider total levels of harvest (cubic volume/year) and levels of management (percent of area of clear-cuts managed by a stand tending regime of given volume and diameter development).

Hall utilized a descriptive forecast of forest development that considered four management options that simulated projected harvest volumes by tree size and yield. Also, the prescriptive capabilities of nomograms, or contour maps of indicator values of two management policies, were developed to display the relationship between indicator variables and resource trade-offs. The reasoning behind this approach was that a minimum of insight into system behavior could be provided by prescriptive analysis, with the analysis, not the decision-maker, doing the optimizing. In addition, "most existing timber supply and resource allocation analyses are mathematically sophisticated and procedurally complex to a degree that precludes an understanding or critique of them by decision-makers; they are not interactive at the policy level."

Smith (1983) used a combination of mathematical optimization and GIS techniques to evaluate development opportunities for Minnesota hardwoods. In this study, aspen stands were allocated to market centers based on a 100 mile circular zone around each market center, and spatial locations of these stands were input to the raster based Minnesota Land Management Information System (MLMIS) to display the relationships of competition between market regions and stand locations in map form. The second approach was to use linear programming to allocate stands to market centers via global minimization of transportation costs. Transport distances were calculated using a matrix that provided actual road distances between the center of each township in the state. Costs were based on a regression model developed by the Minnesota Department of Transportation. Smith recommended the use of systems such as MLMIS to put timber information into spatial perspective for planning and managerial purposes, since adoption of such displays for timber management planning could greatly facilitate the consideration of spatial relationships. An interactive system allowing comparisons of market allocations based on road distances and simple decision rules might replace the linear programming allocations used in this study (Smith 1983).

Transportation Considerations

As described in previous industrial location analysis studies (Hagenstein 1962, Gardner 1966, Dane 1970, Holley 1970, Smith 1983), transportation of wood as a raw material was an important component related to the delivered cost and production of the wood resource. An approach commonly used in the past to estimate the timbershed and associated resource volumes around a wood procurement center has been to develop a series of concentric circles at varying radial distances on a map. This approach may be adequate for initial resource investigations, but should be modified to reflect the detail required for the resource analysis of a specific geographic area.

The use of a series of concentric circles or rings to explain areal development dates back to the mid-1800's with development of von Thunen system theory to explain levels of activity around the nucleus of a system (Faden 1977). At any location within a ring, the same level of activity is assumed to be occuring; as one moves outward to different rings, there is a tendency for the activity to become less "intense." The desirability of any location can be expressed as a single real number, which is based on ideal distances and weights from the nucleus. As this distance may not be a Euclidian metric, the neighborhood of a point may be economically "distant" from the nucleus, though physically close due to the arrangement of the transportation network.

Several researchers have addressed the resource location problem, and have taken approaches different from the circular, von Thunen approach. Smith (1983) used a highway distance matrix to relate transportation distances from the center of each township in the state of Michigan to every other township within the state. This is a generalized approach that probably allows an adequate transportation distance estimate on an area as large as an entire state.

For the household furniture industry, Hopkins (1972) examined the effects of transportation costs upon the location of furniture factories. A regression equation was developed which incorporated not only transportation distance from production to delivery points, but also the traditional variables of labor cost, agglomeration, localization, and urbanization. For the regression equations that were developed, Hopkins demonstrated that the transportation process was a significant determinant of plant location.

Another approach to the highway distance problem was used in an analysis of the average hauling distances for midsouth pulpwood (Beltz 1972). Beltz determined changes in average hauling distance from the pulpwood producing counties surrounding a pulpmill. A scaled grid of 8.68 by 5.21 miles was overlaid on a map and each pulpmill was located at the grid intersection closest to its actual ground location. Each pulpmill reported pulpwood receipts by county, and all pulpwood production in each county was assumed to originate at the approximate centroid of the county. Average weighted hauling distance was then calculated from the gridded pulpmill location to the center of each county in which wood was produced for shipment to that pulpmill. As implied by the author, the accuracy of this approach is not necessarily high, but the method is useful for trend analysis.

In a travel cost analysis of the net economic benefit of a recreation site, Rosenthal et al. (1986) used the Rocky Mountain Station Travel Cost Model (RMTCM). Three methods of calculating distances from a population center to a recreation site were used in RMTCM: airline distance (hypotenuse of a right triangle), checkerboard distance (sum of the lengths of the other two legs of the right triangle), and predicted driving distance. The predicted driving distance was estimated based on a regression model that incorporated both airline and checkerboard distances as independent variables.

In the area of transportation network analysis, Brann (1979) applied multicommodity optimization techniques to a wood fiber transportation problem. Brann evaluated the railroad transportation network problem areas of 1) equipment shortages, 2) assigned car policy, and 3) effects of cross-hauling on transportation costs. The author considered the wood procurement environment to consist only of the woodyard, transportation network, and pulpmill. Brann did not consider wood procurement functions or transportation requirements that might take place prior to the shipment from the woodyard to the pulpmill. The objective of the model was to exchange or trade pulpwood between pulpmills to reduce railroad miles traveled and transportation costs incurred by the pulpmill. An actual example was used to produce a 23 percent reduction in transportation costs. But, several real-world problems of inter-company wood exchange were realized: 1) the railroad would dictate the shipping point of a railcar of wood, 2) an "average" railcar of wood is assumed, and companies may get more or less of the wood that they shipped from their yards, and 3) inventory and accounting of ownership could easily become a significant problem. A system of this nature would probably be effective for the reduction of transportation costs of intra-company wood shipments, but would clearly be difficult to administer in an open and competitive market.

Market Considerations

In the study of wood procurement practices within a geographic region, a descriptive approach to the analysis of wood supply, procurement radii, and transportation modes is often used. These studies are not readily accomplished, because a substantial amount of detailed data is required from wood producers and buyers. Much of these data are confidential and proprietary, and even with a guarantee of anonymity, many potential respondents fail to supply data in a survey of this nature. An example of a study of this sort is one conducted by Manthy and James (1964) to characterize pulpwood marketing practices in the North Central region of the U.S. The objectives were 1) to evaluate how effectively marketing practices reflected wood usage and wood demand, 2) to determine costs and margins of moving products from woods to primary manufacturers, and 3) to determine changes in marketing practices that might strengthen working relations among landowners, producers, and market agents. Information was obtained through detailed interviews of producers, intermediate market agents, and manufacturers. The authors utilized a number of factors: 1) number of pulpmills, with wood usage and dollar value, by mill, 2) wood supply and procurement radii, by volume transported, by product and average distance by mode of transportation, 3) agent source of wood, i.e. mill logging employees, independent producer, or pulpwood dealer, 4) wood purchase agreements, and 5) price and cost comparisons of delivered wood.

A similar but less extensive study was conducted by Baumgartner (1976) for Illinois pulpmills. Baumgartner's objective was to show how the pulp and paper industry in Illinois obtained its wood supply and to document wood procurement areas within that state. Information was obtained through an interview process; statistics requested included the following: 1) volumes by type of wood purchased, 2) prices paid for wood, and 3) wood sources and methods of delivery. Output from this study were a map of the state showing mill locations and pulpwood harvested, by county, and statistical tables showing wood sources, as well as forms and modes of transportation. There was also a discussion of future raw material concerns expressed by the pulpmill procurement managers.

GIS Foundations

Researchers and practitioners in forestry have long dealt with the analysis and manipulation of forest entities within a space-time framework. Historically the primary output of this effort has been in the form of analog (paper) maps that portray data in a georeferenced format. Retrieval and analysis of the data from these maps involves visual inspection and intuitive analysis by the forester. The maps produced may contain large amounts of data and, therefore, map comprehension and analysis of the spatial interaction of the map entities are difficult. In addition, analog maps are expensive and time-consuming to change when updates of the spatial database are required.

The advent of digital computer technology in the early 1960's foreshadowed the development of serious attempts to reduce the spatial data incorporated in analog maps into digital form. This spatial data handling approach has evolved into what is presently termed GIS. A GIS is an approach to the storage, manipulation, and analysis of large amounts of spatial data. Increased emphasis is being placed on the use of GIS in forest resource management.

Many software systems with purported GIS capabilities are currently marketed. According to Marble (1987) many of these software systems should not be termed a GIS, as they are lacking at least one of the required data subsystems. These subsystems consist of data input, data storage and retrieval, data manipulation and analysis, and a reporting system.

The development of a GIS can be an expensive and time-consuming task. Many systems have failed to survive and be useful over time due to a failure by the system developer to appropriately analyze the requirements for building a GIS. Tomlinson et al. (1976) specify that for a GIS to be successful, 1) it must meet a perceived need to gather some data, 2) data must in fact be gathered, 3) data must continue to be gathered, 4) the system itself must be an efficient way to handle data, and 5) a continued need to handle the data must be perceived.

Spatial information is a category of information that has as an attribute a spatial location, extension, or configuration (Lehan 1986). These attributes may be metrical, such as position, shape, and size expressed as spatial coordinates, or topological such as connectivity or adjacency. If relationships are not explicitly stored, performance characteristics and access methods can become unworkable. The human eye can recognize lines and symbols on a map to discern explicit information, but retrieval of this information from a GIS database will not achieve the same result unless attributes are explicitly stored. This problem has led to the development of numerous data structures within GIS software.

The complexity of data structures varies greatly. An example of a complex data structure is a spatial data structure (Haralick 1980). This structure utilizes a series of six separate data identification files and is capable of handling both vector and raster data. The simplest structure is the sequential or spaghetti data model, that is a collection of coordinates to define a point, line, or polygon (Peuquet 1984). The relative complexity of the data structure allows the retrieval of more explicit information, but usually the complexity and time requirements of data input and analysis are increased. Peucker and Chrisman (1975) have characterized the general deficiencies of data structures used in geographic and cartographic analysis as: 1) arrangement of the data is guided by the input stage, 2) different cartographic entities that are stored in different files are difficult to combine, and 3) simple data structures usually lack an indication of a geographic entity with respect to its neighboring entities.

Data structures have also been classified as vector or raster models (French and Taylor 1982, Peuquet 1984). Raster models, or grid cell data structures, utilize a fixed grid system where each grid cell occupies a known location and area, and can be associated with multiple attributes. Raster models are compatible with modern high-speed input/output devices, but are not very compact due to the storage of redundant data values. In addition, problems arise concerning cell size; a smaller cell size necessitates greater data input and storage requirements; a larger cell size results in reduced detail and accuracy.

Vector models are direct digital translations of lines on an analog map. These models are readily used for point, line, and area representation. This approach allows algorithms used for analysis to be direct translations of the manual methods of analysis. The inherent disadvantage of vector models is that spatial relationships must be explicitly recorded or computed, thus an increase in the time and expense of data input is usually experienced.

One of the primary uses of a GIS is cartographic modeling. Cartographic modeling refers to the manipulation of mapped data in various ways fundamental to the analytic function of a GIS (McRae and Cleaves 1986). Berry and Tomlin (1982) have identified four fundamental map analysis operations that are an integral part of the cartographic modeling concept: 1) reclassification of map categories by reassigning thematic values to the categories of an existing map as a function of the initial value; 2) map overlay or "vertical spearing" to assign composite values to thematic regions as a function associated with the regions on existing maps; 3) determination of distance and connectivity that can be a map of concentric, equidistant zones around a target area, or represented as a traversable distance expressed as travel-time, cost, or energy consumption; and 4) characterization of cartographic neighborhoods used to summarize thematic values such as a variable time radius or cartographic distance to a target point.

Cartographic modeling is a flexible tool with a utility limited only by the creativity of the user. As described by McRae and Cleaves (1986), cartographic modeling may be used either by itself or in conjunction with other types of simulation or statistical modeling. But, they state that the role of these models in resource planning and management may center around their heuristic properties more than a specific answer to a specific question.

GIS Applications

Applications of GIS began in 1964 with the development of the Canadian Geographic Information System (CGIS) (Tomlinson et al. 1976). CGIS operates as both a vector and raster based system, and was designed to aid in the development of appropriate land uses in rural areas of Canada. The data input is primarily from 1:250,000 scale maps, and is an evaluation of land capability for use by agriculture, forestry, recreation, ungulates, and waterfowl. CGIS contains census, administrative, and hydrological boundaries. Output from CGIS is usually in tabular form, with acreages displayed by land class for a desired study area, but maps can be automatically produced. This is the first and largest GIS to be constructed and has an ongoing data input function.

In the area of forest resource analysis and land use planning, the Map Analysis Package (MAP) was developed at the Yale School of Forestry and Environmental Studies (Tomlin 1983). MAP is a raster based GIS originally designed to be operated on a mainframe computer. It has been used as an analytical tool in several resource studies (Berry and Sailor 1982, Tosta and Davis 1986, Tomlin et al. 1987). The earliest of these (Berry and Sailor 1982) utilized MAP to spatially characterize the effective timber supply on the 1770 hectare (4372 acre) Harvard Forest. The cartographic model in this study consisted of four submodels: 1) inventory by forest cover type, 2) transportation along existing roads, 3) availability of timber based on proximity to inhabited dwellings, and 4) effective timber supply based on the interaction of the three previous submodels. The final output of this project revealed that the conventional physical inventory of the study forest greatly overstated the actual acreage available for harvest. The authors stated that the advantage of this model was in the capability to perform sensitivity analyses. By varying the constraints of engineering and economic environments, the range of expected timber supply could be estimated.

During the early 1980's, a commercial GIS application, Forest Resources Information System (FRIS), was being developed by the St. Regis Paper Company (now Champion International Co.) and the Purdue University Laboratory for Applications of Remote Sensing (Barker 1982). It was developed in conjunction with the National Aeronautics and Space Administration (NASA) to demonstrate the feasibility of computer-aided analysis of Landsat Multispectral Scanner (MSS) data to broaden and improve the existing forest database. Within FRIS, a pre-stratification capability was used to provide forest cover type maps to determine potential lands for acquisition by purchase and to evaluate the distribution of other forest lands within a given distance to some production facility. In addition the system was to be used to monitor cultural activity on private forest lands within the St. Regis Management Assistance Program and to provide information on the growth and removals of open market wood on non-owned and non-controlled lands. FRIS was operated on a minicomputer system. The original software version did not provide for graphic overlays of major roads, topographic features, and ownership, although this was later developed. Further development of this project has been curtailed due to a change in corporate ownership.

GIS has been a widely used tool within governmental agencies for forest resource management. The Tennessee Valley Authority (TVA) is expanding the role of GIS in planning operations to include all aspects of multipurpose operation and management (Curtis and Rowland 1986). Application of the system is divided into the major areas of strategic planning and operational land management. This minicomputer, vector based GIS does not result in computer produced landuse plans, but is used for the storage and retrieval of resource data, data interpretation and analysis, and development of reservoir plans. In addition, remote graphics workstations are used by the TVA field staff to more effectively manage the land rights data. Manual updating of the complex assortment of fee, sold and transferred land parcels, licenses, permits, and covenants has been very difficult and expensive; this system allows updating of records as soon as relevant changes occur. The GIS analysis and map products from this system are used primarily in a group discussion format to resolve landuse conflicts through compromise and trade-offs.

The vast forest land holdings of the USDA Forest Service make it a logical user organization of GIS technology. Hart et al. (1987) have described an operational GIS for the Flathead National Forest located in northeast Montana. It is based on the Video Image Communication and Retrieval/Image Based Information System (VICAR/IBIS) which operates on a minicomputer and utilizes raster based GIS techniques. Data input to the system includes Defense Mapping Agency (DMA) digital terrain data, Landsat 2 MSS data, timber harvest history, land ownership, precipitation, land types, roads and trails, and hydrology. This GIS has been used for timber harvest planning along streams, viewshed analysis, and wildlife habitat studies.

Tosta and Davis (1986) have reported the use of a GIS for a statewide resource assessment in California. This GIS was built by the California Department of Forestry using a raster based software package called Spatial Analysis and Mapping Geographic System (SPANMAP), which operates on a mainframe computer. Data input was based on a 121.5 hectare (300 acre) grid cell size, and included soils data, watershed boundaries, land use, and digital inventory data collected by the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station (PNW). This digital inventory data included approximately 1300 field plots to input ownership information, and 80,000 aerial photo reference points to indicate volumes and growth stages. Output from this system was primarily in the form of forest cover types by owner class and county for input to a simulation model for resource trend analysis.

In the field of wildlife management, the Task Oriented Multipurpose Information System (TOMIS) was used by Williams (1986) to characterize ruffed grouse habitat on a 1620 hectare (4001 acre) forest in Pennsylvania. The primary data input were habitat types that were interpreted from aerial photos at a 0.25 hectare (0.10 acre) cell size. Each habitat unit contained up to 37 habitat attributes. TOMIS operated on a mainframe computer and was found to be a complicated and time-consuming program to run. For example, a single complicated map could cost as much as fifty dollars to produce. He also felt that a user would benefit from an interactive approach to accomplish certain tasks, rather than the complicated batch processing used by TOMIS.

All of the previously cited systems operate on mainframe or minicomputer hardware. This level of hardware is costly to purchase and operate, and is not readily available to all potential users of GIS. Recent advances in the processing speed, data storage capabilities, graphics capabilities, and associated peripherals of microcomputers have led to the development of microcomputer based GIS technology.

A software package, Micro-GIS, has been developed to operate on both minicomputer and microcomputer systems (Donnay 1986). Micro-GIS is written in Pascal, and has a topological data structure similar to POLYVRT (Laboratory for Computer Graphics and Spatial Analysis 1974) to identify nodes, chains, and polygons. When used with less sophisticated systems, the data structure can be converted to a simple sequential structure. Micro-GIS handles continuous quantitative data as isoline maps using weighted means and polynomial interpolation methods. It can also accommodate trend surfaces for three-dimensional interpretation. Donnay reports that the primary tasks of Micro-GIS are mapping, geographic data processing, and communicating with hardware devices missing from the microcomputer environment.

Klock et al. (1986) reported a project to classify and stratify the vegetative fire fuels on the Okanogan National Forest in North Central Washington. The database includes vegetative species, conifer size class, crown closure, average elevation, aspect, and slope classes. The areal coverage is approximately 3 million acres, with a spatial resolution of a 0.24 hectare (0.6 acre). The system operates on an IBM PC/XT microcomputer using software written by ERDAS, Inc. This system has the capability to couple the analytical capability of a GIS with field plot data to provide the spatial distribution of vegetative and abiotic factors that control current and potential productivity. Individual files of various layers can be displayed for visual interpretation, overlaid to make composite data layers, or outputted to scaled georeferenced color maps for field use.

A GIS software package that has been modified from mainframe application for microcomputer use is the Professional Map Analysis Package (pMAP). This system was demonstrated by Berry (1986) who further developed an existing timber accessibility model. In considering harvest factors, the database consisted of forest cover types, hauling distances by road types, and accessibility. The study area was the 1770 hectare (4372 acre) Harvard Forest. This raster based system is based on a 0.25 hectare (0.62 acre) cell size. PMAP operates on a personal computer system having a minimum of 256 kilobyte RAM, math coprocessor, and a single disk drive. Output for this analysis is in the form of line printer maps and statistical tables.

In a recent study by Johnston (1987) the use of a minicomputer system for data input and a microcomputer system for GIS analysis was reported. Map data were digitized using the Odyssey software, a vector system developed at the Harvard Laboratory for Computer Graphics. Odyssey has a spaghetti data structure and operates on minicomputer hardware. The GIS analysis was accomplished on an IBM PC/XT and PC/AT microcomputer using the pMAP software. The study area was a 3 by 14 mile watershed along the Kedgwick River in New Brunswick. The study objective was to enhance timber management in concordance with visual quality, landscape ecology, potential natural vegetation, fire management, wind management, and production and economics; each of these submodels was weighted by the land manager for relative importance within polygons composed of forest stands within the study area. Different scenarios were then pursued and suitability maps were produced from each submodel resultant from overlay operations. This process required considerable manual intervention, as total weight within any grid cell could not exceed 100 percent. The output maps were not results of mathematical optimization techniques, but rather were derived from an iterative procedure that was continued until the land manager was satisfied that a submodel allocation approached the total required area for each landuse.

Another microcomputer system is μ-GIS (Maggio and Wunneburger 1986). The software for this system is written in GW BASIC and uses the commercially available database manager, Knowledge Man (Micro Data Base Systems, Inc.). μ-GIS is a vector based software system and has the minimum hardware requirements of a microcomputer with at least 256 kilobyte RAM and two, 320 kilobyte floppy disk drives. Data input/output devices are presently limited, and no resource studies utilizing this system have been reported in the literature.

Summary

Wood procurement is an integral part of the forest products industry. The impact of wood procurement activities in the southern U.S. is important, especially when evaluated in the context of the large percentage of forest land owned by NIPF landowners. These landowners may assume an even greater importance in the future, as ownership of some wood conversion plants is changing to non-forest based companies and as industrial forest land is being divested into smaller, private ownerships.

The techniques used in past wood supply and location analysis studies were examined. Much time and money has been expended for data gathering in these studies, but once these studies were completed, sensitivity analyses could not readily be conducted. Various scenarios carried out in a GIS format have the potential to portray a wealth of information that may otherwise escape the forest resource policy makers.

Some of the transportation and market considerations relative to wood procurement have been evaluated. Much of this work has been purely descriptive in nature, and consequently managers have relied on intuition to determine market effects within the competitive procurement environment.

The basic requirements of a GIS as evaluated by researchers in the field, and several examples of past GIS applications were provided. GIS has been shown by the referenced studies to have an effective impact on the forest resource decision making process. This impact will probably become even greater in the future as continual applications of GIS technology are developed for readily available microcomputers. GIS is an effective means of maintaining a spatial database and of providing information to policy makers in a vivid format.

METHODS AND PROCEDURES

Study Area

The primary purpose of this study was to develop a spatial pulpwood procurement model of the pulpwood procurement zones for a procurement region in Louisiana. The northwest region of Louisiana, Region 5 as defined by the USDA Forest Service Survey Unit, was chosen as the study area (Figure 1). The primary reason for choosing this region was the relative importance of forestry and the timber industry in this region as compared to the remainder of the state. Louisiana had a 35 percent increase in capital productivity from 1972 to 1977 (Maki et al. 1986) and the northwest region of the state was a major contributor to this growth.

The first objective of this study was to describe and model the forest land area, ownership patterns, transportation network, pulpwood production and forest inventory of the study area. The northwest region has a total land area of 2.433 million hectares (6.011 million acres), of which 1.782 million hectares (4.401 million acres) are classified as forest land (Rosson and Bertelson 1985); this is a regional average of 73.2 percent forest land. The region is comprised of 13 parishes, with a forest land composition ranging from 50 to 94 percent (Table 1).

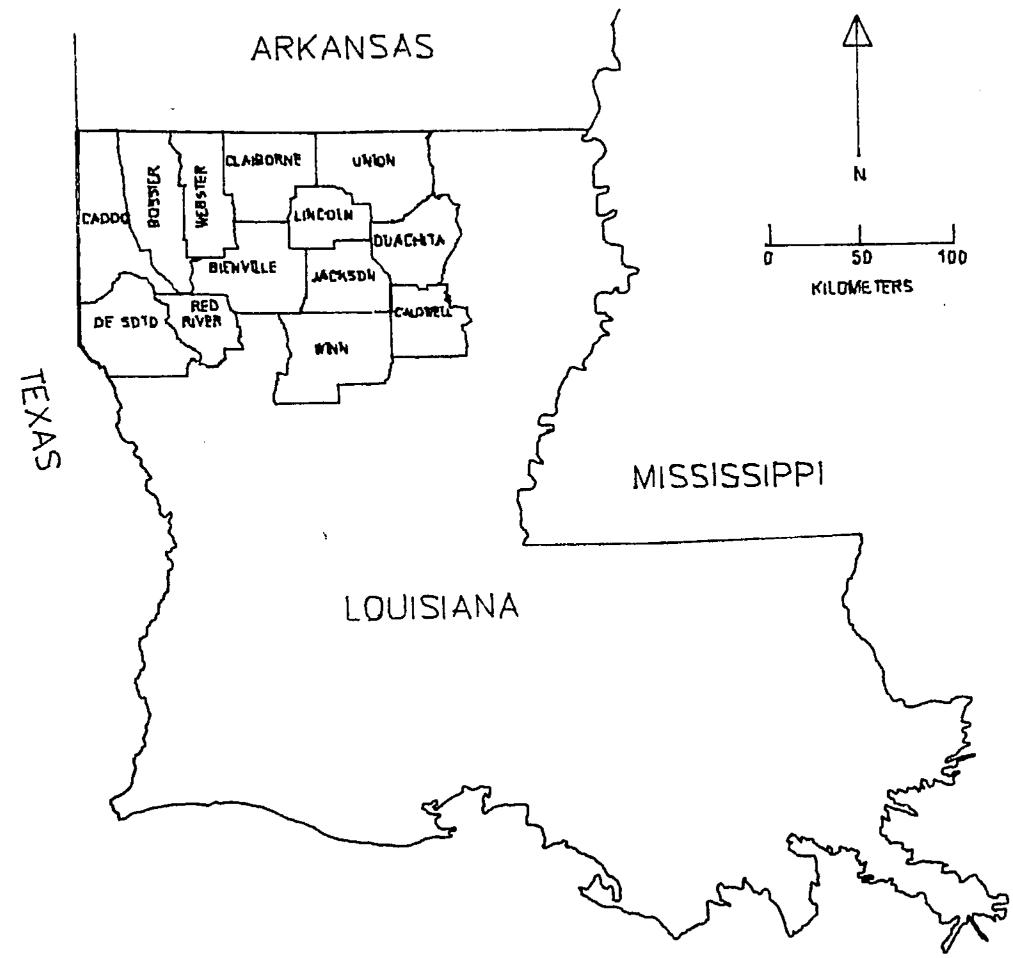


Figure 1. Map of the northwest region of Louisiana study area.

Table 1. Acreage of northwest Louisiana study area by parish.

Parish	All Land	Forest	Non-Forest	Forest Percentage
	(M Hectares)			
Bienville	213.1	176.9	36.2	83
Bossier	224.5	148.6	75.9	66
Caddo	243.1	120.9	122.2	50
Caldwell	140.1	102.7	37.4	73
Claiborne	198.9	161.3	37.5	81
De Soto	231.7	152.7	79.1	66
Jackson	150.1	135.5	14.6	90
Lincoln	122.4	90.6	31.7	74
Ouachita	163.8	93.2	70.6	57
Red River	104.2	54.9	49.3	53
Union	234.4	193.2	41.2	82
Webster	159.4	117.9	41.5	74
Winn	247.9	233.3	14.5	94
Total	2433.5	1781.7	651.8	73

Source: Rosson and Bertelson (1985).

The forest land ownership pattern of the region is shown in Table 2. The NIPF ownership for Region 5 is 61 percent of the forest land in the region, which is comparable to the statewide NIPF ownership of 60 percent (May and Bertelson 1986). Within this region, the individual forest land ownership is 52 percent of the forest land, and is considerably higher than the statewide individual ownership of 37 percent. Therefore a potentially greater amount of procurement effort must be expended in securing wood from the individual private landowner in this region than the state as a whole.

Forest industry ownership is 31 percent of the forest land within this region (Table 2). Scattered throughout the region are three wood-using pulpmills, and 34 wood concentration yards that purchase pulpwood from a variety of sources (Figure 2).

In 1986, this region was the source of 1.33 million cords (128 cubic feet per cord) of the statewide harvest of 3.5 million cords of pine pulpwood and 0.55 million cords of the statewide harvest of 1.30 million cords of hardwood pulpwood. The harvest contributed a regional stumpage value of $24.8 million (La. Office of Forestry, 1987). The 1986 pulpwood production by parish for the northwest region is shown in Table 3.

Table 2. Northwest Louisiana timberland area ownership by class and parish, 1984.

Parish	Forest Land (M Hectares)	Govt.	Industry	Farmer	Corp.	Indiv.
		Forest Land Ownership (Percent)				
Bienville	176.9	00	60	08	00	32
Bossier	148.6	09	22	03	04	62
Caddo	120.9	05	00	07	14	74
Caldwell	102.7	18	42	07	02	30
Claiborne	161.3	07	08	00	05	80
De Soto	152.7	00	19	12	06	63
Jackson	135.5	00	57	00	03	40
Lincoln	91.6	00	05	03	00	92
Ouachita	93.2	11	19	03	11	56
Red River	54.9	00	27	04	08	62
Union	193.2	09	30	08	05	49
Webster	117.9	15	17	11	04	52
Winn	233.3	18	55	00	01	26
Total	1781.7	08	31	05	04	52

Source: Rosson and Bertelson (1985).

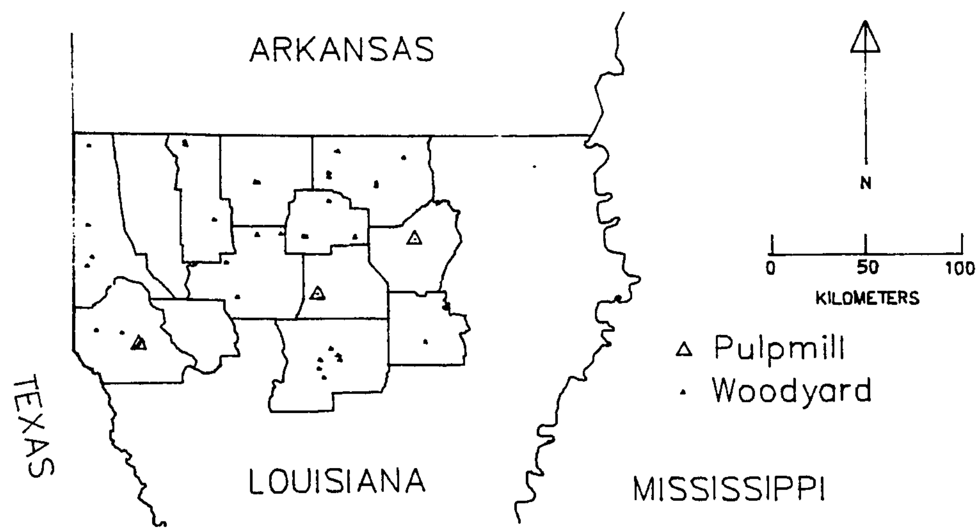


Figure 2. Location of pulpmill and wood procurement centers in the northwest region of Louisiana.

Table 3. Northwest Louisiana region 1986 pulpwood removals, by type and parish.

Parish	Total		Per Forested Hectare	
	Pine	Hardwood	Pine	Hardwood
	(M cords)		(cubic meters - m^3)	
Bienville	166.5	50.1	3.41	1.02
Bossier	62.0	44.2	1.51	1.08
Caddo	36.9	17.5	1.11	0.52
Caldwell	54.9	34.2	1.93	1.21
Claiborne	105.8	39.7	2.37	0.89
De Soto	141.9	51.5	3.36	1.22
Jackson	209.9	59.2	5.60	1.58
Lincoln	96.9	33.3	3.87	1.33
Ouachita	59.3	33.8	2.30	1.31
Red River	42.0	14.7	2.77	0.97
Union	147.5	81.8	2.76	1.53
Webster	50.5	29.1	1.55	0.89
Winn	156.2	61.5	2.42	0.95
Total	1,330.1	550.6	2.70	1.12

SOURCE: Louisiana Department of Agriculture and Forestry, Office of Forestry (1987).

The study region was assumed to be a closed region for the purposes of resource evaluation. The timber resource outside of the regional boundary was not evaluated in this project. Adjacent USDA Forest Service Survey Region areas could possibly be incorporated into a future study to consider the effects of competition outside of the current study region.

Data Acquisition

Several forms of data were acquired during this project. Primary and secondary digital data were obtained, in addition to the descriptive and quantitative information obtained from procurement personnel in the region. To enhance the transportability of the study approach, data were acquired mainly from publicly available sources, although this was not possible in all instances. These data were input in a GIS for use in the analysis of the study area. The following sections are detailed descriptions of the data that were acquired.

Transportation Network

The transportation network of this region is comprised of railroad systems and the public highway system. Water transportation, primarily the Red River, is not presently used for the shipment of pulpwood and was not considered.

Location of railroad lines were digitized into the database from the U.S. Geological Survey (USGS) topographic maps at a scale of 1:250,000. For study purposes it was assumed that unless described as abandoned, the railways as depicted on the topographic maps were operational.

The public highway system in the study region is the primary means of transporting pulpwood. The highway transportation network was separated into five broad highway classes: interstate, principle arterial, minor arterial, hard-surface collector, and gravel (Louisiana Dep. of Highways 1974). The location of these roads were digitized from USGS topographic maps, with most input being at a scale of 1:62,500. Each highway class was digitized into a separate file to allow GIS analysis at the degree of road network complexity appropriate to the user's level of inquiry. It was originally anticipated that these highway locations would be verified from 1:90,000 scale black-and-white panchromatic photographs from the National High Altitude Program (NHAP), but it was determined that the wood procurement GIS would be used to make general assumptions and trend analyses rather than to imply specific point values, and the greater detail was not necessary. As evaluated by Walsh et al. (1987), "point values should not be extracted from GIS products unless the user is aware of the high levels of error possible; otherwise decisions based on such a practice will be fatally flawed."

Data describing the transportation network was input based on the Universal Transverse Mercator (UTM) grid coordinate system. UTM is a widely used system of georeferencing for cartographic products, and for this reason was used as the primary method to georeference all data input.

Forest Inventory

Information concerning forest inventories in the study region was obtained from the USDA Forest Service, Southern Forest Experiment Station, Forest Survey Unit located in Starkville, Mississippi. Data were gathered during the 1984 decennial inventory and were organized in both field plot coded format and summarized timber volumes and land ownership by parish.

The forest inventory consisted of 823 variable sized plots in Region 5, and were located on an approximate 3 by 3 mile square grid. Each plot is permanently, but inconspicuously, identified and remeasured at least once every 10 years. Although the areal coverage of this inventory is extensive, the amount of data acquired at each plot is intensive. Variables extracted for input to the wood procurement GIS included volumes of growing stock by broad cover type, land ownership and use, and average net annual growth of growing stock by species group.

These data would be a more valuable source of input for a GIS if exact plot locations were available. Knowledge of these locations would allow a linkage of forest cover types and inventory data. However, the USDA Forest Service personnel maintain that to provide exact plot locations would violate the right of confidentiality of information of private citizens; therefore, information could only be summarized by the least common geographical unit (LCGU). In this study, the LCGU was an individual parish, therefore, published summary data were more useful. Thus, homogeneity within each parish polygon had to be assumed, which increased the level of abstraction of the study.

Procurement Environment

The second objective of this study was to characterize the wood procurement practices of the pulpwood purchasers and to develop a database of wood volumes purchased at pulpmills and wood concentration yards in the study region. The procurement practices were characterized from the results of a detailed questionnaire sent to the procurement manager at each wood concentration yard and pulpmill within the region (Appendix I). Questions designed to produce quantitative data for GIS input were posed in the following areas:

1) raw material percentage by source - wood dealer, cutting contract, purchased stumpage, gatewood, or fee land,

2) volumes of wood purchased by wood type - pine or hardwood,

3) form of raw material - roundwood or chips,

4) perceived procurement zones, and

5) transportation modes used and average hauling distances for purchased wood shipments.

Responses were used to estimate the removals of wood within a parish on as small a geographic unit as possible.

Questions relating to procurement zones as perceived by the wood procurement manager required a response to the same basic question in two different formats. First, the respondents were given a map showing their procurement location with eight, 45-degree corridors radiating from that point. Each corridor represented one-half of one of the four quadrants surrounding the procurement center location (Figure 3). Respondents were asked to give the percentage of raw material procured from each of these corridors. Next, they were asked to give the percentage of their wood supply procured from a series of concentric circles or zones circumscribing their procurement center at radii of 25, 50, 75, 100, and 100+ miles.

The percentage of wood volumes procured by corridor and zone with reported wood purchases were combined to produce an estimate of pulpwood removals by procurement center based on a relatively small, variable size geographic area. This facilitated a more realistic portrayal than only circular procurement zones of wood movement to each procurement

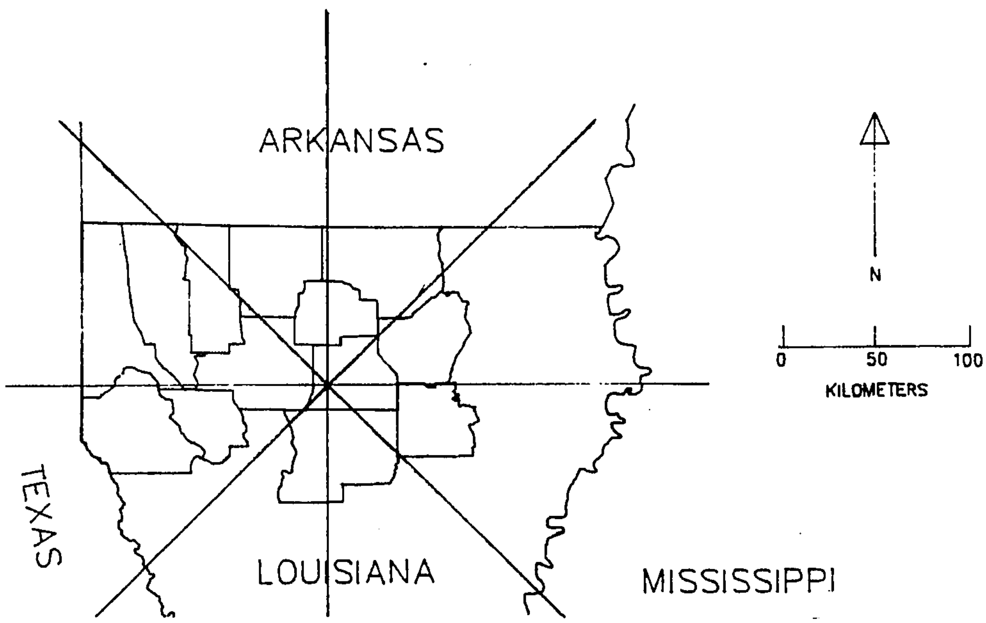


Figure 3. Example map given to procurement managers to provide wood volume procurement percentages by corridor.

center. In addition, overlay capabilities of the GIS would allow one to measure the interaction of competing wood procurement centers and to determine those areas of greatest and least potential competition, when evaluated in conjunction with inventory availability, for future wood procurement efforts.

The questionnaire also contained several questions to which responses could not be readily formatted for GIS input. These questions concerned:

1) pulpwood volumes procured by wood source,
2) types of procurement and harvesting systems used,
3) a tract evaluation rating scheme used for timber purchase decisions.

This area of questioning was designed to provide information that, although not necessarily useable in a pure GIS format, would enhance the evaluation of the wood procurement environment in the study region.

Computing Facilities

This study was designed to maximize the use of microcomputers for data input, analysis, and output. This approach should enhance the system applicability to potential users, and also be a cost effective means of data analysis. The use of a mainframe computer was required in the study, primarily because of hardware constraints required for input of digital tape data. This problem is not inherent with every microcomputer GIS, but is a temporary limitation of the system used in this study.

Microcomputer System

The majority of the data input, processing, and output was performed on the microcomputer systems of the Remote Sensing Laboratory, School of Forestry, Wildlife, and Fisheries, Louisiana State University, Baton Rouge. There are two separate microcomputer systems in this laboratory. Both of these systems operate in a stand alone capacity.

The first system was used primarily for digitizing data from topographic maps. The major components of this system are an IBM PC/AT computer with 512 kilobytes RAM and a 20 megabyte internal hard-disk, and a Hitachi 36 by 48 inch electronic digitizing tablet (Figure 4). The AutoCad software package (Autodesk, Inc.) was used to input the required map data. This software provided data input and interactive editing capabilities that exceeded the capabilities of the data analysis software.

The second microcomputer system was used for data conversion and analysis. The major components of this system include an IBM PC/AT computer with 640 kilobytes RAM and a 20 megabyte internal hard-disk, a 20 megabyte external disk drive, an Aydin RBG graphics monitor, and a Tektronix color printer/plotter (Figure 5). The primary software used for this part of the project was ReSource

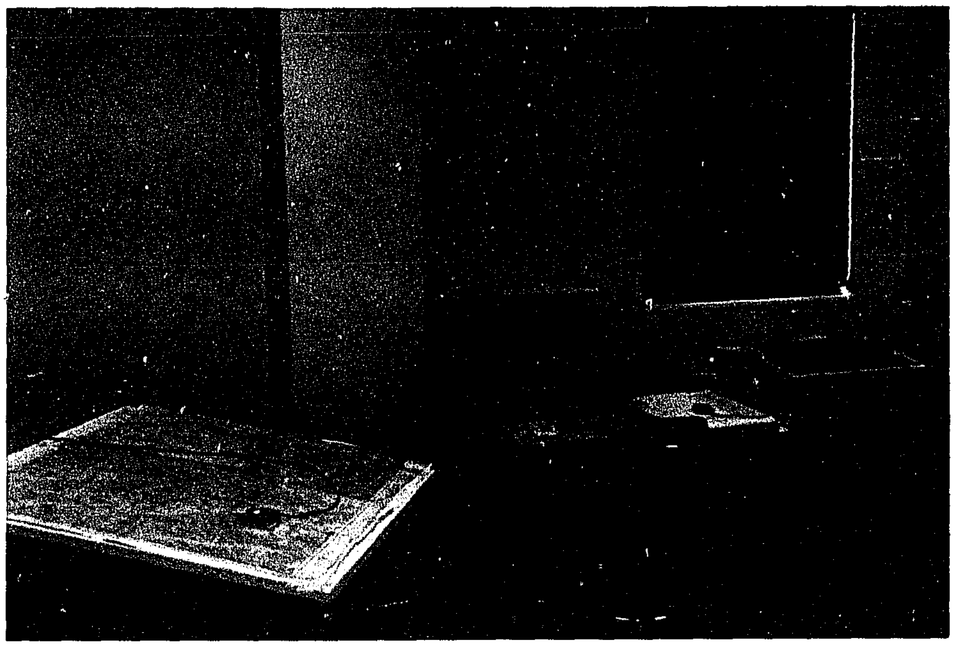


Figure 4. Configuration of data input hardware.

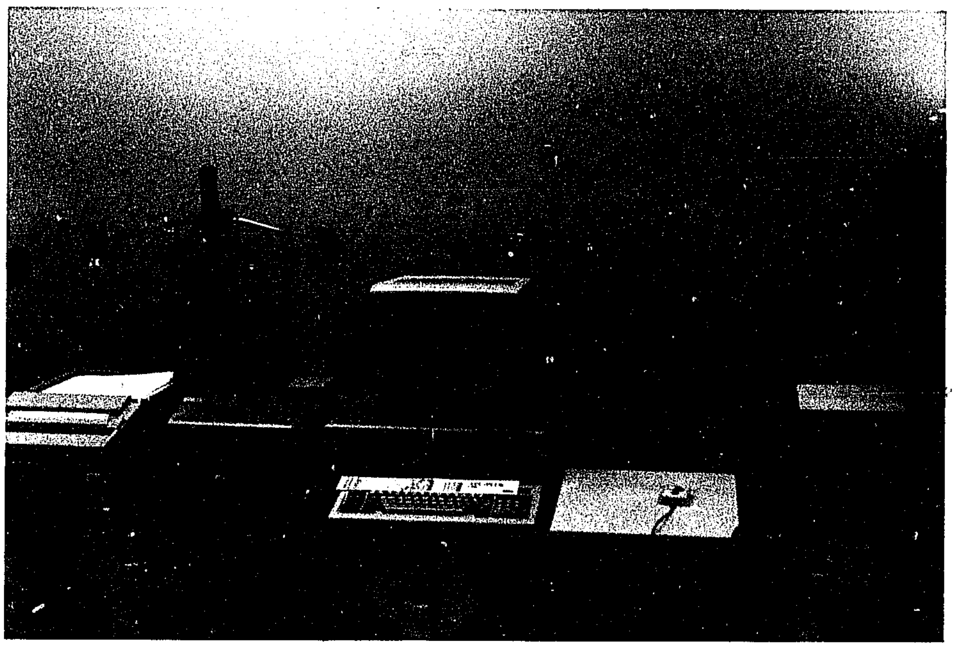


Figure 5. Configuration of data analysis and output hardware.

(Decision Images, Inc. 1986). ReSource is written in A Programming Language (APL) and contains both image processing and GIS capabilities. The system accepts data input in both vector and raster format, but accomplishes most of the analytical GIS functions in the raster format. A significant feature of this software is user accessibility to the source code to allow software modification as required.

The ReSource software uses a basic sequential data structure for the input of vector data. The database for this system allows the attachment of an unlimited number of attributes to polygonial entities, with as many as 18 different levels per attribute per file (Figure 6). The most useful GIS function contained in this system is the capability to perform image arithmetic. This capability is performed in the raster mode, and has a spatial resolution of 512 by 512 pixels. With image arithmetic, map files can be added or subtracted, or manipulated through primitive operations such as "and", "or", and "nor". Areas of intersection of different attributes or like attributes in different map files can be readily determined and located on a new map created from the intersection of any combination of maps of the same georeferenced area.

In the assignment of attributes to entities, considerable forethought must be given to the value assigned to each attribute. Although the attribute has a character name, it actually is interpreted as a color value in digital

DRAW FILE

Flg	X Y
4	100,125
5	100,150
5	125,200
5	100,125
.	.
.	.

ATTRIBUTE FILE

Symbol	Value	Index
1	5	4
.	.	.
.	.	.
.	.	.

INDEX FILE

Index	Name	X Y
4	PINE	115,170
.	.	.
.	.	.
.	.	.

Figure 6. File structure of the ReSource software used for storage of vector data.

format when image arithmetic is performed. Therefore, attribute value assignments must be chosen to insure that maps resultant from cartographic modeling are clearly interpretable. This is especially important because the system does not support user queries in character format, but must be derived from the interpreted results of map overlay operations.

A significant shortcoming of the ReSource software is the inability to determine neighborhood connectivity and to erect barriers. Because of its simple, spaghetti data structure, manual intervention and heuristic interpretation is required in the performance of simulation analysis. The modeler must be aware of the locations of natural and land ownership barriers and the extent of the transportation network to simulate a wood concentration yard relocation.

The data structure of the data input software, AutoCad, and the data analysis software, ReSource, were not directly compatible. Therefore, to maintain the flexibility of maintaining two workstations available to the system, a program was written in APL at the Remote Sensing Laboratory to extract the required data elements of vector coordinates and draw flags in the AutoCad format and convert these to the basic sequential structure required by ReSource.

Other Computer Systems

The use of computer systems in addition to the microcomputer systems in the Remote Sensing Laboratory was limited as much as possible. But, the large storage space requirements and data formats of some of the input data exceeded the capabilities of the present microcomputer hardware.

Statistical analysis of the wood procurement questionnaire responses and USDA Forest Service regional inventory information was conducted on the Louisiana State University, System Network Computer Center mainframe computer, an IBM 370 Model 3084. The data storage requirements for the inventory data exceeded the microcomputer storage capacity and were more readily accommodated on the mainframe system. These data were analyzed with the Statistical Analysis System (SAS) software.

Data Preparation

Accuracy of a GIS

As described by Walsh et al. (1987), a number of inherent and operational errors could occur within every GIS. Inherent errors derived from the data input from secondary sources are difficult to identify and correct. These errors include those made in the primary preparation of cartographic products, both analog and digital. The topographic map sheets used in this project were assumed to meet USGS map accuracy standards. Operational errors resulting from manual digitizing of spatial features and the location and determination of attributes of these features have been visually verified throughout the project to insure as accurate a product as possible.

A basic analytical operation of a GIS is the production of map overlays, that is the combination of maps or layers of the same area, but with the map entities described by different attributes. The errors present in each new layer are multiplicative, and can become quite large after several layers have been combined. With this characteristic considered, point and small area data values can be quite variable, and should not be extracted with high expectations of spatial accuracy. In the wood procurement GIS, the intent was for spatial trend analysis, rather than determining specific point location values resulting from overlay operations and attribute intersections.

Study Area Resolution

The land area of the study region, 2.433 million hectares (6.011 million acres), is contained in an irregular polygon in the northwest portion of the state. A spatial resolution of 12 hectares (29 acres) per grid cell results if the study area is viewed in its entirety. But, to produce a map size suitable for production in this study required a 76 hectare (188 acre) grid cell size. This is not a significant hindrance, as pulpwood demand data resolution is extremely coarse.

Transportation Isolines

As the majority of the pulpwood in the region is transported by truck, it was hypothesized that actual highway distance from a wood procurement center would more accurately portray procurement zones than a series of uniform circular zones. A manual method was used to determine these highway distances on the topographic maps. A map measure instrument was calibrated to the map scale and traced along the minimum classification of primary arterial highways as identified on the topographic map. Flag points were delineated at 40.2 kilometer (25 mile) distance intervals from respondent locations. These points were input into a separate file for each procurement center, and individual procurement center boundaries were contoured using a spline function in ReSource to produce highway transportation isolines (Figure 7). The procurement zone delineation using a circular von Thunen system approach was also produced as a comparison to the transportation isoline approach (Figure 8).

Procurement Segments

From the questionnaire responses of the wood procurement managers, an estimate was made of the pulpwood demand from a relatively small geographic area. The estimate of removals in a spatial context was the basis used to determine levels of competition between wood concentration yards and to achieve the third study objective

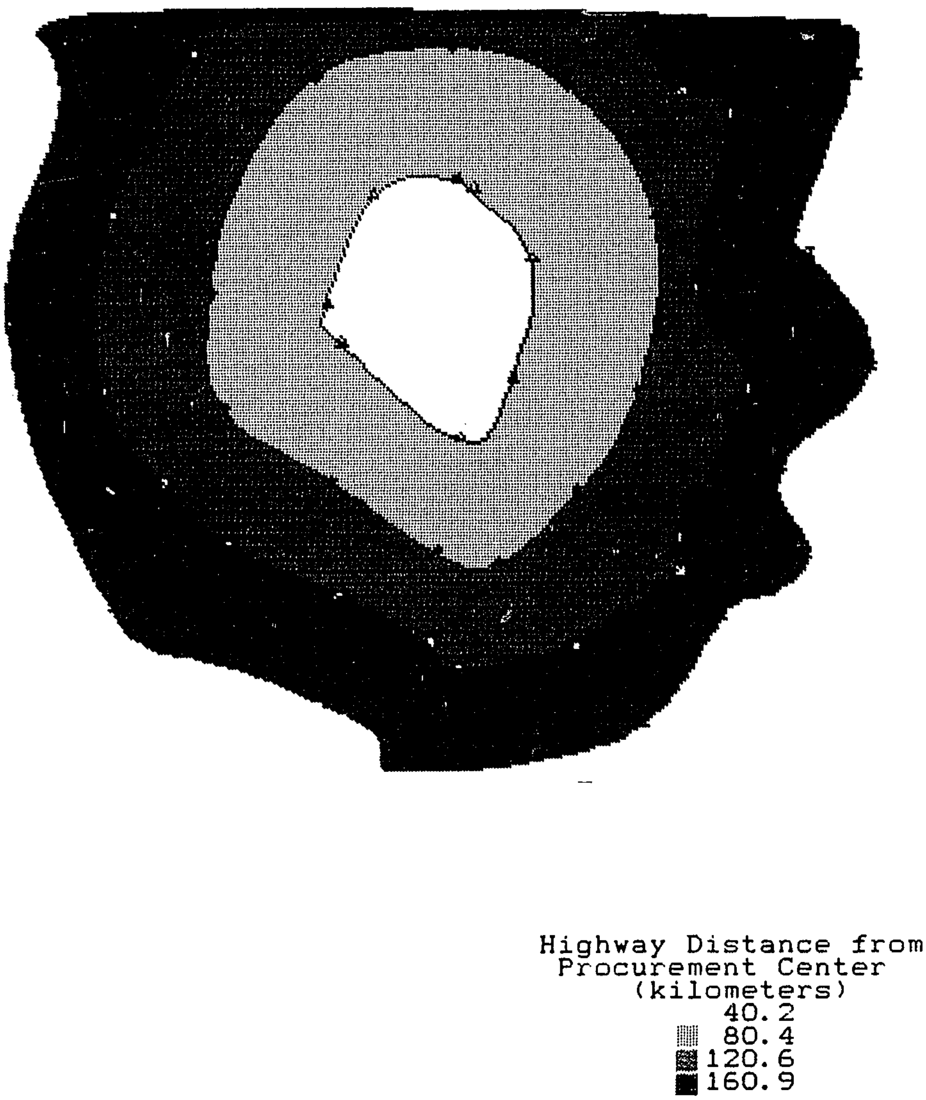


Figure 7. Example highway transportation isolines.

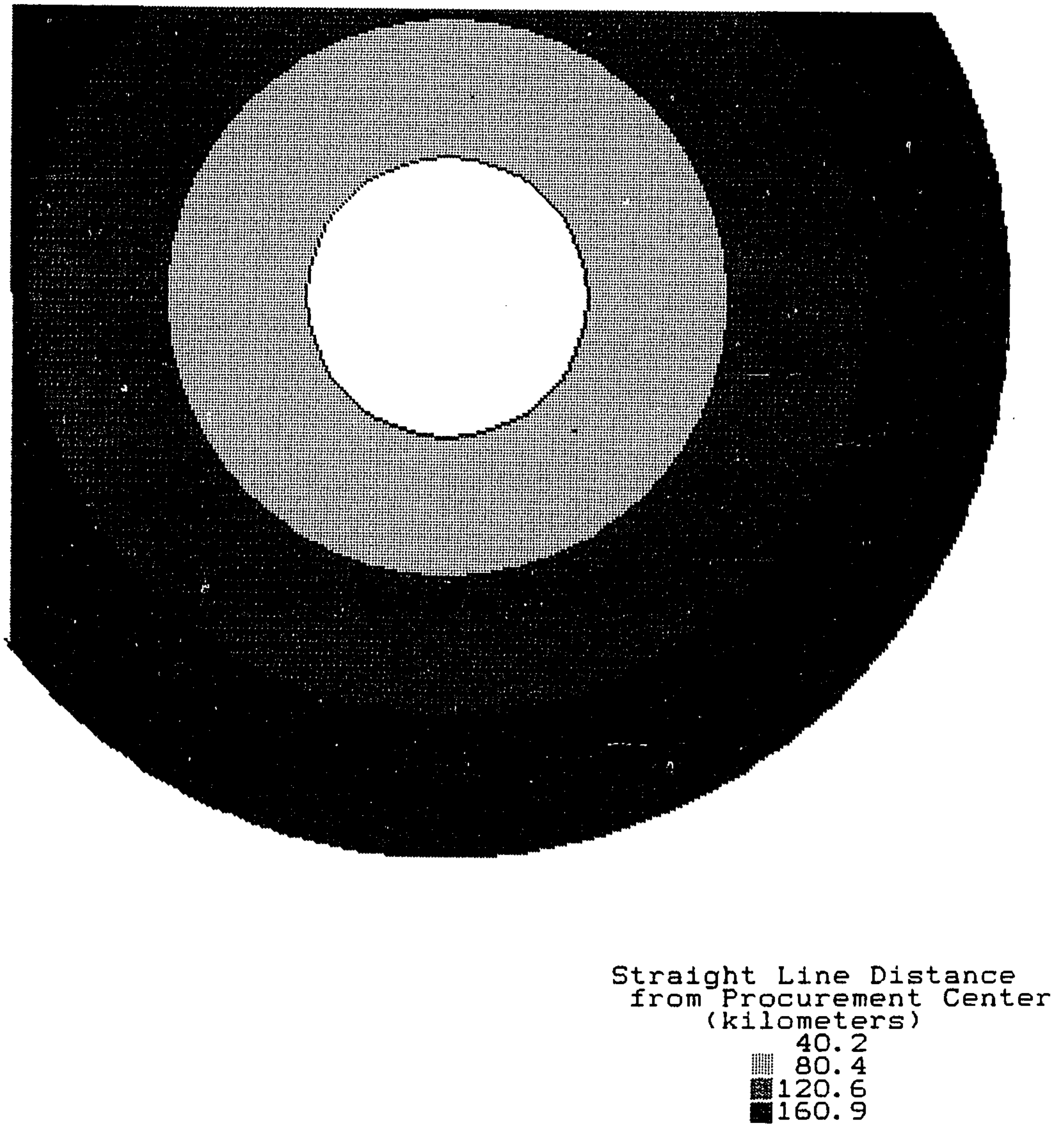


Figure 8. Example procurement zones based on a von Thunen system delineation.

of simulating a restructure of the regional market competition. Procurement areas for each wood procurement location were delineated by the percentage of pulpwood volumes received from an eight-corridor evaluation projected from the procurement center, and also as a four-level concentric, circular zoned system. The combination of these two responses resulted in a 160.9 kilometer (100 mile) radius procurement area to be divided into 32 variable sized procurement segments (Figure 9). These segments for the circular von Thunen system ranged in size from 58,040 hectares (224 square miles) for the nearest segment to 447,482 hectares (1727 square miles) for the most distant segment. The percentage of total wood volume procured from each segment was estimated to be:

$$S_{ij} = C_i * Z_j$$

where: S_{ij} = percent of wood procured in segment ij,

C_i = percent of wood procured in corridor i,

Z_j = percent of wood procured in zone j,

for: i = corridors, 1 to 8,

j = circular zones, 1 to 4.

To obtain the pulpwood volumes for each segment, the annual pulpwood volumes reported as being procured at each procurement center were multiplied times the segmented

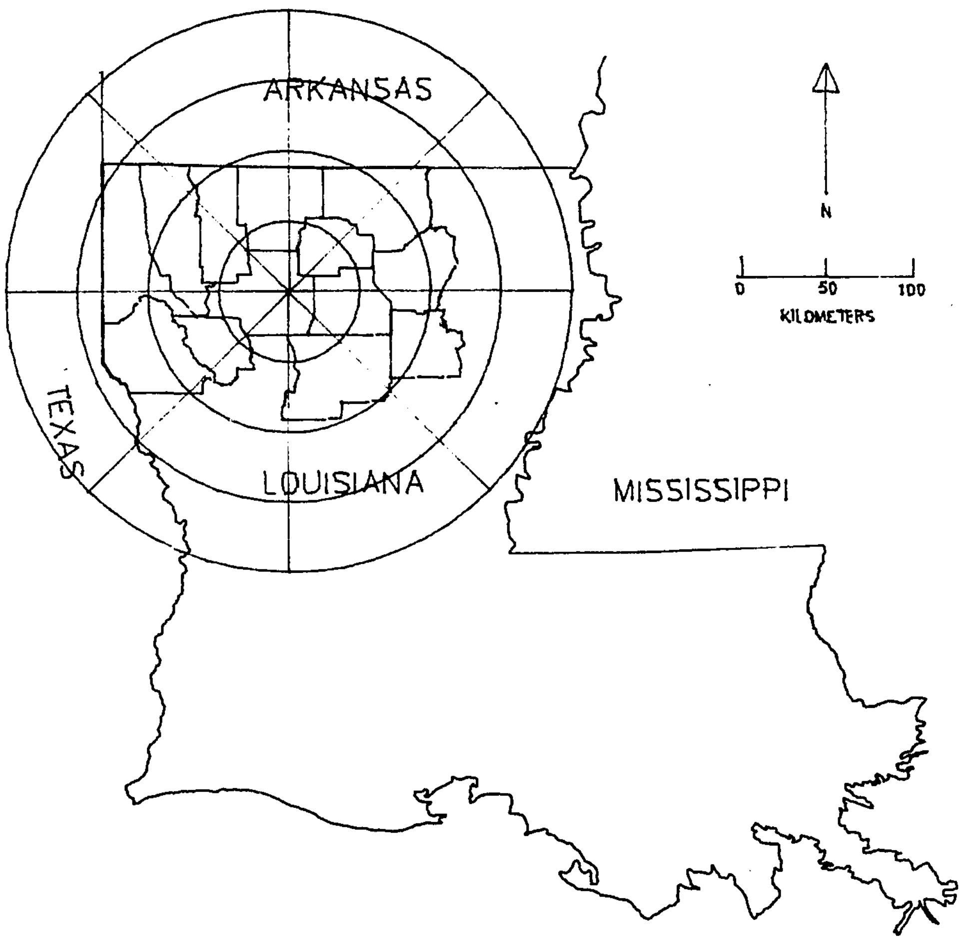


Figure 9. Procurement segments calculated from the combination of procurement corridors and circular von Thunen system delineation.

percentage of pulpwood procurement. It must be realized that the calculated volume of pulpwood procured in each segment can only be an estimate of actual wood removals. This estimate is based on the assumption of homogeneity within each segment, circle, and corridor, and the provision of accurate responses from the procurement managers who participated in the study.

Wood procurement centers from which no questionnaire results were obtained were considered for study purposes to be "average." These locations were assigned segmented wood volumes based on the reported pulpwood volumes procured by the wood concentration yards that participated in the survey.

Spatial Submodel

A procurement zone model based on actual highway distance was produced using regression analysis. The objective of this model was to more accurately predict the circular von Thunen procurement zones based on highway distance. The approach used is analogous to that described by Rosenthal et al. (1986). The model is:

$$D_i = \beta_0 + \beta_1 S_i + e_i$$

where: D_i = predicted highway distance from the wood procurement center to the i^{th} mile radius,

S_i = actual straight line distance from the wood procurement center to the i^{th} mile radius,

e_i = error term,

β_0 = intercept, and

β_1 = regression coefficient.

The development of this model allowed the wood demand defined by a transportation isoline to be represented as a circular von Thunen system. Using this representation, each wood procurement center was developed as an individual overlay model to facilitate manipulation with image arithmetic. In this manner simulation analyses could be performed to determine the effects of moving one or more woodyards to a new location.

The data for this model were collected by sampling four points of each transportation isoline for each of the woodyards. The pulpmill transportation isolines were considered to be fixed, due to the immobility of a pulpmill compared to a wood concentration yard. Wood concentration yards that were located in the areas of greatest wood demand were simulated to be moved to another area having adequate timber availability within the study region. This was an iterative approach to reduce the areas of highest demand intensity within the region due to the tendency for wood concentration yards to be clustered, and thus producing high levels of competition.

Overlay Models

In addition to the overlay models previously described, overlays were developed to represent the timber resource within each parish. These overlays were:

1) ownership percentage of NIPF and forest industry,

2) pulpwood production per acre of pine and hardwood,

3) total growing stock volume per acre of pine and hardwood, and

4) volume growth per acre of pine and hardwood.

These overlays were intended to provide resource location and availability information to aid in the decision-making process of relocating wood concentration yards to areas of lesser competition for the pulpwood resource. A flowchart of data development and overlay production and analysis is presented in Appendix II.

RESULTS AND DISCUSSION

The results and discussion section will be treated in two parts. The first part will be a description of the pulpwood procurement environment and a discussion of the pulpwood procurement practices used in the study region. This section will be based on the results and analysis of the questionnaire mailed to the pulpwood procurement managers in the region. The second section will be a discussion of the GIS and the results of the simulation analysis performed to demonstrate a method of redistribution of pulpwood market purchase levels due to excess competition.

Descriptive Characterization

Questionnaires were sent to 42 wood concentration yards and four pulpmills. Participation in the study was greater than originally anticipated, with a 70 percent return rate from potential respondents. Of the four pulpmills, one was a roofing felt mill which no longer purchased pulpwood or chips; completed questionnaires were returned from the remaining three pulpmills. Within the wood concentration yard category, three yards were found to be operated by owners who had other woodyards in the study region, three wood yards were no longer in business, two were not actually in the pulpwood procurement business, and ten wood concentration yards did not provide a response. The non-responding managers were contacted by telephone and requested to participate in the study. All declined on the basis of the amount of time required to complete the questionnaire or confidentiality of the information requested. A total of 27 of 40 usable questionnaires were received for analysis (3 pulpmills and 24 woodyards). For the purpose of input to the GIS, the wood concentration yards that did not participate in the study were assigned wood production volumes based on the reported volumes of the study respondents. The frequency table and wood volume procured by the wood concentration yards is shown in Table 4. The responding woodyards reported the procurement of 679,381 cords of pine and 339,883 cords of hardwood, for a total of 1,019,264 cords of pulpwood. This was an average of 67 percent pine and 33 percent hardwood.

The distribution reported of total wood volumes was nearly normal, but statistical tests for normality did not allow the acceptance of the hypothesis that the reported volumes followed a normal distribution (Wilks normal = 0.6058). Distribution of the reported pine and hardwood volumes also did not conform to a known distribution. Therefore, the ten non-responding woodyards were assigned total pulpwood procurement volumes based on the median of 25,000 cords as reported by the woodyard respondents. Based on the reported pine/hardwood percentage, 16,750 cords were

Table 4. Frequency table of total pulpwood volumes procured at northwest Louisiana woodyards that responded to the survey questionnaire.

Pulpwood purchases			
Volume Class (Cds.)	Frequency	Volume Class (Cds.)	Frequency
10,000	2	46,000	1
12,000	1	50,000	1
16,000	1	126,000	1
18,000	3	150,000	1
20,000	4	220,000	1
26,000	3		
30,000	2		
38,000	1		
40,000	2		

Median Reported Volume: 25,000 cds.

Mean Reported Volume: 42,469 cds.

Standard Deviation: 50,366 cds.

assigned as pine pulpwood, and the remaining 8,250 cords were assigned as hardwood.

Wood Forms and Sources

The study respondents reported pulpwood procured in two basic forms, roundwood and chips. Chips were classified as field chips or mill residue based on the residue percentage reported by the respondents (Table 5). Residue chips from solid wood conversion facilities comprised only 7.2 percent of the pulpwood purchased. The greatest proportion of the pulpwood production, 72.4 percent, was produced in the roundwood form.

The combined pulpmill and woodyard purchases of 3,426,991 cords of pulpwood greatly exceeded the 1,880,773 cords of pulpwood production reported in the study area in 1986 (La. Dep. of Agric. and Forestry 1987). There are two major sources of error in a comparison of this nature. First, the volumes reported by the study respondents did not originate entirely within the study area, but extended into neighboring regions and states. Second, a significant portion of the wood volumes reported on the questionnaire as being procured by the pulpmills were probably also reported as procurement volumes by the wood concentration yards. (The pulpmill respondents did not specify the specific wood concentration yards from which they purchased pulpwood). Fulfilling the market role of wood procurement middleman is a primary purpose of a wood concentration yard, and based on

Table 5. Wood usage in cords, by form, at wood concentration yards and pulpmills in northwest Louisiana, as reported by respondents only. (with assigned volumes for nonrespondents).

Wood Form	Woodyards	Pulpmills
	(cords)	
Study Respondents Only:		
Roundwood	1,019,264	1,656,545
Field Chips	184,122	567,060
Residue Chips		268,418
Total	1,203,386	2,492,023
All Pulpwood Procurement Centers:		
Roundwood	1,295,992	1,656,545
Field Chips	234,111	567,060
Residue Chips		268,418
Total	1,530,103	2,492,023

the reported average inbound wood transport distance of the pulpmills, it was probable that the regional wood concentration yards accounted for a large proportion of the pulpwood requirements for the three pulpmills in the region.

The wood procured at the respondent locations was derived from six basic sources (Table 6). Wood dealers are agents at an intermediate level in the market between the pulpwood producer and the purchasing pulpmill, and may be considered as contractors or employees of the pulpmill. Cutting contracts are agreements to harvest specified volumes of stumpage from timberlands over a specified time period. Gatewood is that pulpwood purchased at the woodyard from independent pulpwood producers who purchase and harvest their own stumpage. Gatewood is usually the least expensive form of delivered pulpwood; the reported median gatewood price of pine pulpwood was $41.44 per cord and $32.23 per cord for hardwood pulpwood. These prices are less than the published average delivered prices of $44.00 per cord for pine pulpwood, and $34.50 per cord for hardwood pulpwood (Timber Mart South 1987). Fee land is that land for which the wood procurement center has ownership by title. Fee lands were the source of a small percentage of pulpwood procurement, relative to the 31 percent of industrial land ownership. The wood dealer system for pulpwood procurement provided a significant percentage of the pulpwood produced in this region (Table 6), and reinforced the premise that

Table 6. Total pulpwood volumes by source, as reported by northwest Louisiana study respondents, excluding residue chips.

	Woodyards		Pulpmills	
Source	Cords	Percent	Cords	Percent
Wood dealer	224,958	18.7	1,009,433	45.4
Cutting contract	153,634	12.7	244,001	11.0
Purchased stumpage	264,370	22.0	161,640	7.3
Gatewood	277,500	23.1	242,460	10.8
Fee land	265,109	22.0	343,848	15.5
Unclassified	17,815	1.5	222,223	10.0
Total	1,203,386	100.0	2,223,605	100.0

the wood dealer system is a major contributor to the pulpwood market in the study region.

Transportation Modes

Most of the pulpwood and chips procured by the respondents were reported as transported by truck. The inbound pulpwood shipments via truck were 3,295,506 cords and accounted for 89.2 percent of the total pulpwood transported; rail shipments were 399,923 cords and accounted for 10.8 percent of the total pulpwood transportation requirements (Table 7). Average inbound truck hauling distance was 41.4 kilometers (25.7 miles) for the reporting woodyards, and 81.9 kilometers (50.8 miles) for the pulpmills. The average inbound hauling distance to pulpmills with rail and truck shipments combined was 87.7 kilometers (54.4 miles). This is approximately 16.1 kilometers (10 miles) greater than the 72.6 kilometers (45 miles) reported by Beltz (1971) for all pulpmills in the state. The importance of the highway network was implied from the high percentage of pulpwood transported by truck.

Wood Procurement Agents

A large volume of the pulpwood harvested in the southern U.S. is produced by wood dealers, who act as intermediate agents. The responsibilities of these dealers are variable, and the level of responsibility is based on

Table 7. Transportation modes for total pulpwood purchases of northwest Louisiana study respondents.

	Woodyards		Pulpmills	
	Cords	Percent	Cords	Percent
ROUNDWOOD				
Truck				
Shortwood				
Bobtail	270,135	22	159,782	06
10 cd. Tlr	159,348	13	547,670	22
Longwood	581,968	48	660,802	27
Truck Total	1,011,451	83	1,368,254	55
Rail	7,813	01	288,291	12
Water	00	00	00	00
Rail & Water Total	7,812	01	288,291	12
Total Roundwood	1,019,264	84	1,656,545	67
CHIPS				
Truck	184,122	16	731,658	29
Rail	0	00	103,820	04
Water	0	00	0	00
Total Chips	184,122	16	835,478	33
Total Procurement	1,203,386	100	2,492,043	100

the degree of control allowed or required by the purchasing pulpmill. At the end of the spectrum where there is the least amount of control exercised by the purchasing pulpmill is the independent wood dealer, who purchases stumpage, harvests, and sells pulpwood on the open market. This class of wood dealer usually sells pulpwood to the pulpmill that provides the greatest profit margin, and this dealer type has the greatest potential to take advantage of pulpwood market opportunities to increase profitability; but, this dealer class often lacks the security of a long-term contractual relationship with a purchasing pulpmill. At the opposite end of the degree of control spectrum is the pulpmill controlled wood dealer, who as an agent operates or supervises harvesting operations for a pulpmill and/or purchases pulpwood as a contractor. In the extreme case, pulpmill employees act as wood dealers, and eliminate the middleman, but at the expense of an increase of pulpmill liability and employee overhead. Based on the wood concentration yard respondents, 65 percent of the pulpwood in roundwood form was produced at woodyards owned and operated by independent wood dealers, 10 percent was produced at woodyards owned by forest industry and operated by wood dealers, and 25 percent was produced at woodyards owned and operated by forest industry. In addition to signifying the continued importance of the wood dealer in the total wood procurement alignment, the high percentage of pulpwood produced by independent dealers is an indication that new, independent producers could move in and out of the marketplace as opportunities appear.

Tract Evaluation

To purchase pulpwood stumpage on the open market requires potential buyers to make not only a timber appraisal to determine stumpage value, but also to evaluate the numerous peripheral attributes of a timber tract. These non-timber attributes can affect the stumpage price offered by the wood procurement forester to the timberland owner. The study respondents rated nine factors on an ordinal scale of one to ten; higher numbered responses indicated a greater degree of importance attached to a given factor. Scores were calculated on a ranking of mean responses for each factor, weighted by the number of woodyard locations operated by each respondent (Table 8).

The two factors that ranked highest were access to the timber tract from existing roads and distance from the tract to the initial delivery point. These factors probably reflect the perceived relative contribution of transportation costs to total delivered wood costs. Access from existing roads is impacted not only by the significant costs of road construction, but also by the need to secure a right-of-way for ingress and egress to the timber tract. Negotiating a right-of-way across a neighboring landowner's property can impose a potential cost in terms of both time

Table 8. Tract purchase evaluation factors ranked in order of importance by northwest Louisiana study respondents, with mean responses weighted by number of woodyard locations owned.

Factors Considered	Ranking	Mean
Access to existing roads	1	5.28
Distance - woods to mill	2	4.83
Soil conditions	3	4.81
Terrain	4	4.60
Total tract volume	5	4.26
Contract provisions	6	3.75
Tract size	7	3.58
Public highway quality	8	2.72
Ownership	9	2.19

and money to the timber buyer, and effectively reduce the residual stumpage value. Distance of the timber tract to the initial delivery point was expected to greatly affect timber purchase decisions, as pulpwood is a relatively bulky commodity, which incurs high transport costs relative to the delivered value. Many of the wood dealers in the study region shifted this responsibility to the pulpwood producer, as 41 percent of the respondents did not provide a graduated freight allowance for pulpwood transport based upon distance from the delivery point.

Consideration of the soil conditions and terrain were ranked third and fourth among the tract evaluation factors. These two factors can become quite significant on specific tracts, and can increase the risk of failure to complete the harvesting function due to the effects of adverse weather conditions on poorly drained soils. The importance of these two factors is that the adaptability of timber harvesting systems that are controlled by a wood procurement forester are "fixed" in the short run, and timber tracts must usually be purchased to conform to the harvesting systems currently available to the timber buyer.

Total tract volume and size of the tract considered for purchase ranked fifth and seventh, and reflected the economy of scale related to the harvesting systems used by the respondents. In that the cost to move harvesting equipment from tract to tract can become substantial in terms of both physical moving expense and volume production lost to the system, a timber harvester would usually prefer to remain on a single timber tract for as long a time period as possible. Therein lies the importance of total tract volume; as total timber volume increases, system moving costs per unit of production volume decreases. Area of the tract was considered by the respondents to be less important than total tract volume. This is probably due to the fact that a small tract size can be compensated by higher timber volumes per acre. There are minimum tract sizes and timber volumes required for economical operation of various harvesting operations (Cubbage 1981), but on a relative basis in this study, total tract volume was considered by the respondents to be more important than tract size.

Contract provisions and timber tract ownership were ranked sixth and ninth among the evaluation factors. The low rankings belie the fact that 81.6 percent of the stumpage reported by the respondents was from purchased timber tracts, and possibly signifies a general landowner attitude in the study region towards timber management for industrial use. Contract provisions in the harvesting contract include time allowed to harvest, reforestation provisions, and seasonal restrictions among others. Tract ownership factors include the owner's willingness to sell, past timber purchase experiences of the procurement forester with an owner or class of owners, and the general attitude held by a timberland owner towards timber harvesting.

The factor that ranked next to last in the evaluation was the public highway quality from the timber tract to the initial delivery point. This was the only factor that did not receive at least one rating of ten, and was rated only as high as seven by any respondent. This may be an indication of a uniform level of highway quality for timber transport purposes in the study region, or that the highway quality was at least adequate.

Procurement Zone Perception

The portion of the questionnaire that provided significant information concerning the areal distribution of wood procurement effort was that of procurement corridors and circular zones. Pulpwood was not acquired equally from a 360 degree radius around a wood procurement center; nor was it acquired uniformly from within a series of concentric, circular zones surrounding a wood procurement center. This approach was developed to preclude the need to assume homogeneity of pulpwood volumes procured from a large area, such as the 508,543 hectares (1,963 square miles) contained within a 40.2 kilometer (25 mile radius), to 8,136,688 hectares (31,416 square miles) within a 160.9 kilometer (100 mile) radius. Logically, pulpwood is not produced uniformly over areas of these magnitudes, but within these zones is harvested from smaller areal segments based on stumpage availability, procurement effort expended, and competition for available timber, in addition to other localized factors peculiar to each individual timber stand. Previous studies have relied heavily on the assumption of homogeneity within large procurement radii, but this tends to mask the effects of competition between individual wood procurement centers.

Determining the locations of pulpwood drain on as small a geographic area as feasible was the purpose of determining the wood supply percentage by both corridor and radial zone. Almost 75 percent of the roundwood procured by the wood concentration yards originated within a 80.5 kilometer (50 mile) radius, and only 8 percent was procured beyond a 120.7 kilometer (75 mile) radius (Table 9). Fifty percent of the roundwood procured by the responding wood concentration yards was within a 61.6 kilometer (38.3 mile) radius of the wood yard. The pulpmills required a much larger procurement area. Approximately 45 percent of the roundwood procured by the pulpmills originated within a 80.5 kilometer (50 mile) radius, and 19 percent was procured beyond a 120.7 kilometer (75 mile) radius. Fifty percent of the roundwood procured by the pulpmills was within a 85.8 kilometer (53.3 mile) radius of the mill. The calculated 50 percent procurement radius for wood concentration yard respondents produced a quite different portrayal of average procurement zones than the average transportation distance of 41.4 kilometers (25.7 miles) that they reported. But, it was virtually the same

Table 9. *Response statistics of procured roundwood by corridor and radial zone, by responding wood concentration yards and pulpmills in northwest Louisiana.*

Radial Zone (Miles)	Woodyards Cords	Woodyards Percent	Pulpmills Cords	Pulpmills Percent
25	254,920	25.01	298,545	18.02
50	475,829	46.68	451,837	27.28
75	204,554	20.07	590,928	35.67
100	77,711	7.62	184,181	11.12
100+	6,250	0.62	131,054	7.91
Total	1,019,264	100.00	1,656,545	100.00
Corridor				
NNE[1]	156,125	15.32	153,918	9.29
ENE	151,991	14.91	123,009	7.43
ESE	99,186	9.73	174,927	10.56
SSE	116,664	11.45	184,200	11.12
SSW	106,479	10.45	365,310	22.05
WSW	133,173	13.07	223,127	13.47
WNW	131,455	12.90	247,854	14.96
NNW	124,191	12.18	184,200	11.12
Total	1,019,264	100.00	1,656,545	100.00

[1] N=North, E=East, S=South, W=West.

for pulpmill respondents as the 87.6 kilometers (54.4 miles) that they reported.

A combination of zone and corridor delineation was interpreted to be a more realistic estimate of procurement areas than either delineation individually. The combination of zones and corridors was used to produce procurement segments of individual procurement areas for more specific analysis in a GIS.

There was no logical significance in an average corridor delineation when all observations were combined, as the direction of wood volumes purchased by each woodyard respondent were different. The corridor delineation was important only when attached to a specific wood procurement location as an indicator of directional wood procurement from that procurement center. Therefore, a uniform distribution of 12.5 percent of the pulpwood volume procured per procurement corridor was used to delineate the wood procurement zones of the non-respondents (Figure 10).

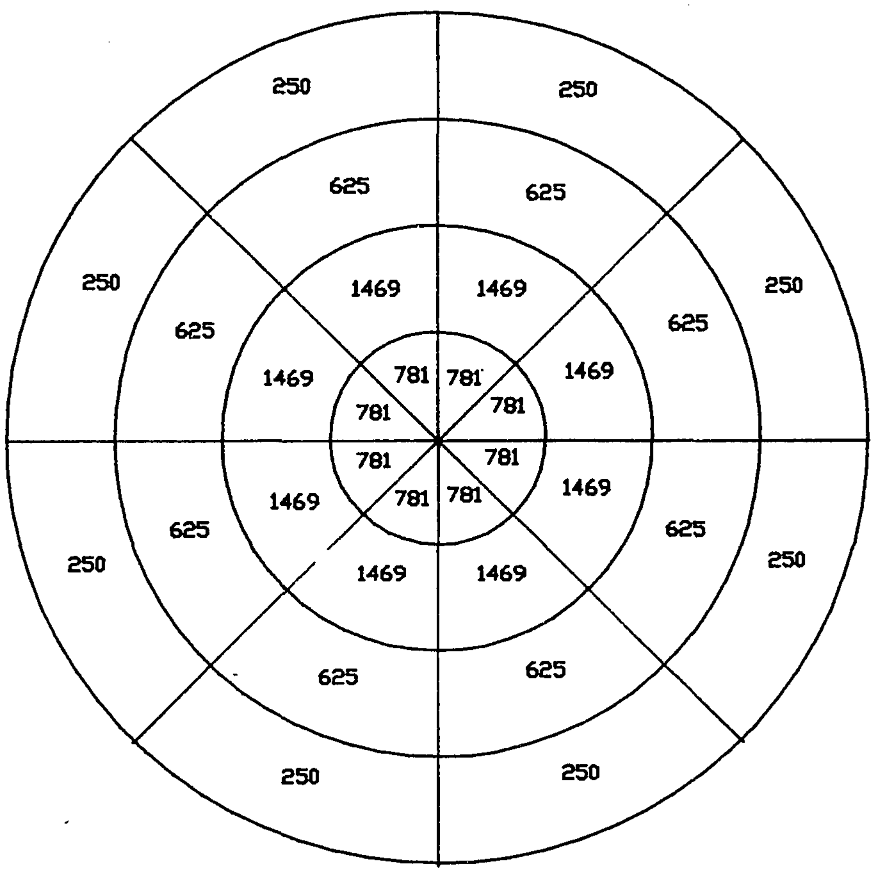


Figure 10. Combination of corridor and zone delineation of median reported pulpwood volumes in cords, which were assigned to nonresponding woodyards.

GIS Analysis

The basis for using a GIS to analyze the wood procurement environment of the study area was to develop an approach to evaluate and analyze of the components that comprise this environment. In this analysis, demand was not strictly interpreted; the pulpwood purchases reported by the study respondents were assumed to be an expression of pulpwood demand by the procurement centers in the study region. With the GIS, spatial demands for the pulpwood resource were determined and cartographic modeling techniques were used to emphasize or de-emphasize future wood procurement efforts for specific areas within the study region.

It was not reasonable to combine the pulpwood demand overlays of the pulpmills and the woodyards, therefore, a separate demand analysis was done for each respondent category. All other overlays that were developed were applicable to both analyses.

Relative Competition Analysis

Data Manipulation

Due to the fact that the GIS analysis was performed in a raster mode, and with only 18 unique attribute level delineations available, wood demand volumes by procurement segment were assigned to 1 of 18 different volume classes.

Each class was assigned a specific numeric value with a distinctive color code (Table 10).

With the exception of the first, second, and last volume class, 1000 cord intervals were used to maintain additivity of demand classes. However, the capability to maintain precise reported pulpwood requirements by segment and respondent was lost. This was a limitation of the GIS software, but the approach was deemed appropriate to exhibit relative competition among pulpwood procurement centers in the study region.

Demand for pine, hardwood, and total pulpwood procured was calculated for each study respondent by procurement center. The number of relevant (non-zero) segments was based on the wood procurement manager's questionnaire response, and varied from 8 to 32. The procurement zone greater than 160.9 kilometers (100 miles) was not used, because it usually fell outside of the study region, and less than 1 percent of the total woodyard procurement and 8 percent of the total pulpmill procurement was obtained beyond this zone. For each respondent location, appropriate pulpwood demand values were attached near the centroid of each segment (Figure 11). This file was stored in a vector format.

Table 10. Wood procurement attribute values applied to pulpwood volumes of northwest Louisiana wood procurement centers, by procurement segment.

Wood Volume (cords)	Attribute Value	Color Value
0	0	White
1 - 1500	1	Red
1501 - 2500	2	Green
2501 - 3500	3	Blue
3501 - 4500	4	Black
4501 - 5500	5	Yellow
5501 - 6500	6	Pink
6501 - 7500	7	Orange
7501 - 8500	8	Tan
8501 - 9500	9	Burgandy
9501 - 10500	10	Lavender
10501 - 11500	11	Cyan
11501 - 12500	12	Chartreuse
12501 - 13500	13	Lime
13501 - 14500	14	Navy
14501 - 15500	15	Brown
15501 - 16500	16	Dark Brown
> 16500	17	Beige

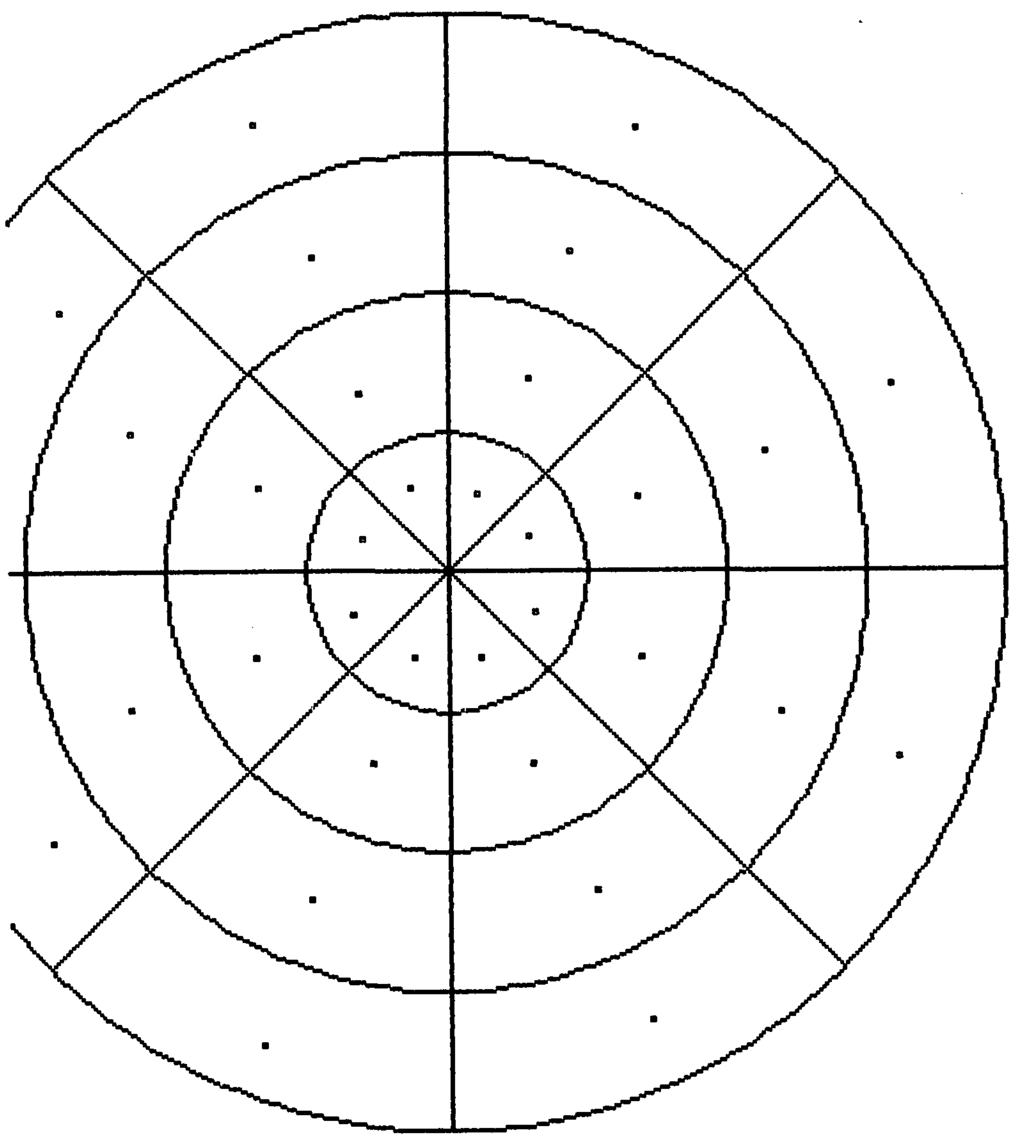


Figure 11. Example respondent vector file showing attribute attachment; dots in procurement segments represent attribute values (see Table 10 for legend).

Each vector file was then rasterized to allow the attached attribute color to fill all cells within the respective procurement segment polygon (Figure 12). Prior to saving the rasterized file, it was clipped along the borders of the study region in order to maintain wood demand comparisons solely within the study region (Figure 13). The procurement zone files by wood type were then added to determine the additive spatial competition for the pulpwood resource. To differentiate competition levels, a histogram of wood demand value frequency was produced to determine distinctive demand class categories. Color values of increasing intensities were created for each demand class to enable visual pulpwood demand categorization. These categories were of either three to four levels, and the boundaries of the categories were digitized from the graphics monitor and saved for further overlay and acreage analysis, by parishes that comprised the study region.

Other Procurement Demand Factors

In addition to the relative demand for pulpwood, other factors useful in the evaluation of the total wood procurement environment were considered. Overlays were produced for ownership of timberland by NIPF landowners and forest industry (Figure 14). The input data for this overlay were presented in Table 2. Parishes that contained high percentages of NIPF timberland ownership were assumed to be more likely to have stumpage available to the

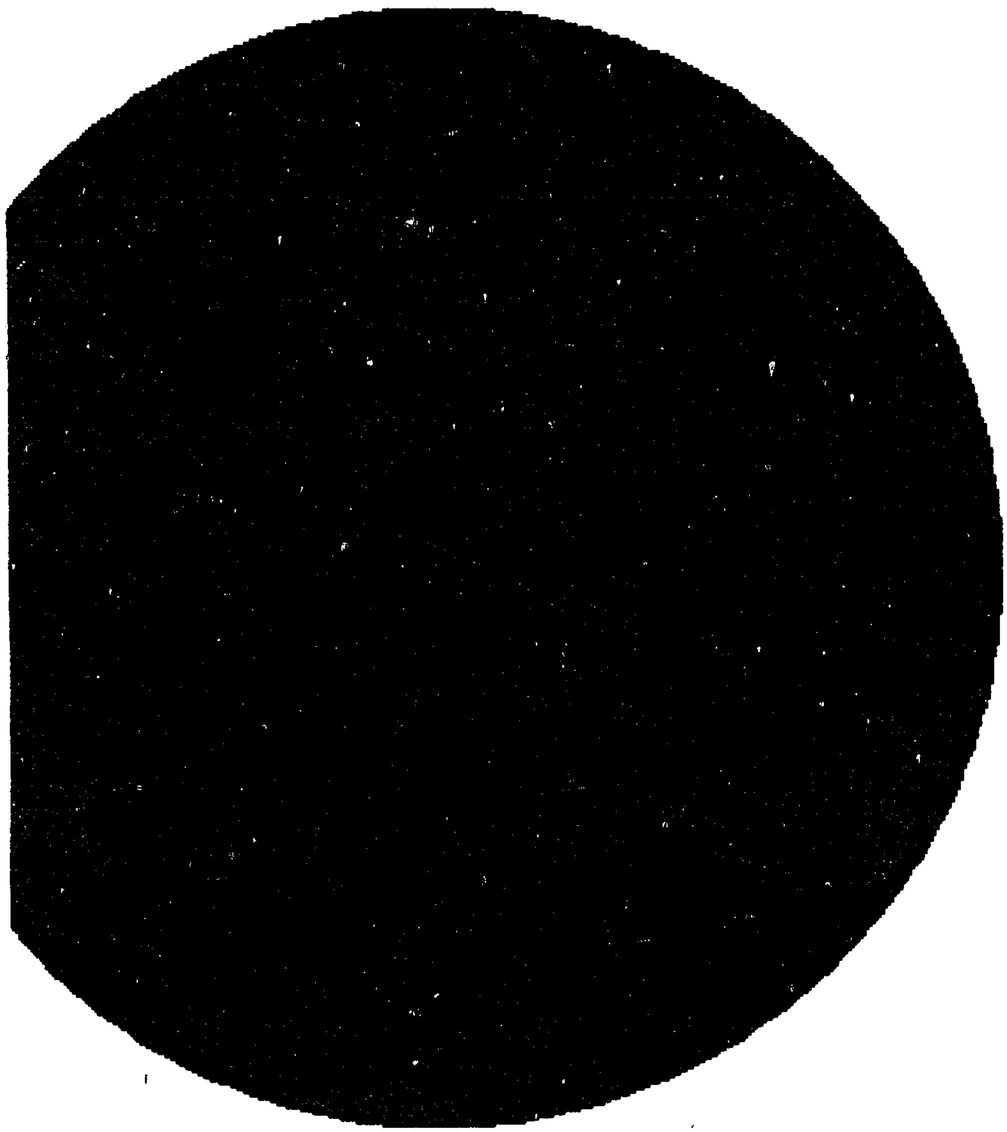
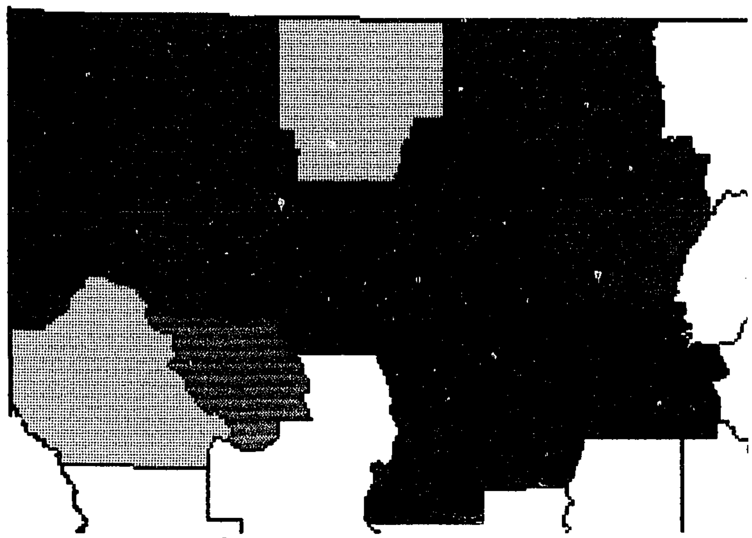
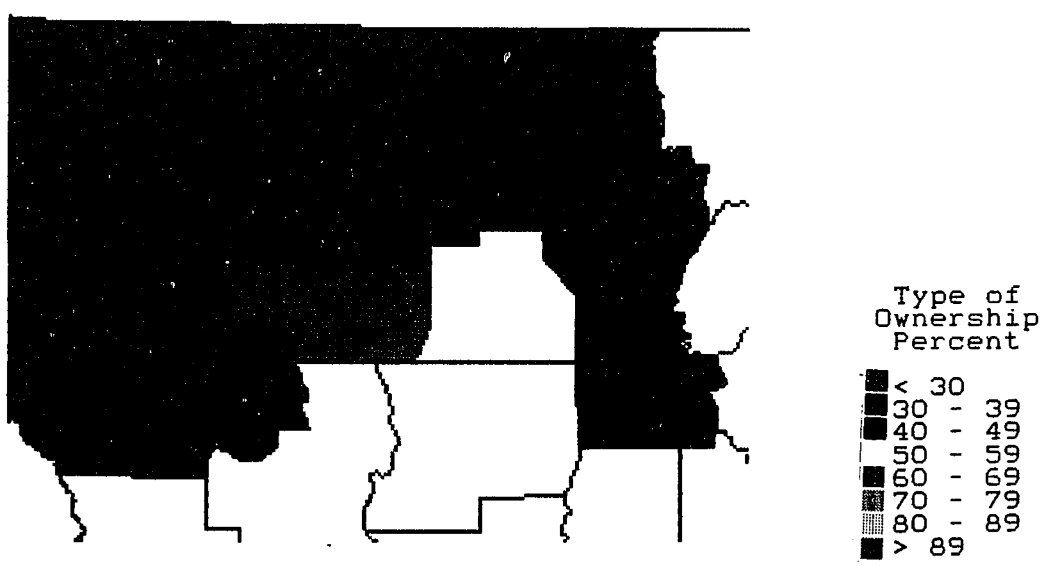


Figure 12. Rasterized file showing procurement segments filled with appropriate procurement class densities (see table 10 for legend).

Figure 13. Example rasterized file after being clipped to borders of study region (see Table 10 for legend).



a. NIPF



b. Forest Industry

Figure 14. Timberland ownership map file.

competitive pulpwood market. Timber harvested from forest industry timberland is usually produced for use in that company's manufacturing facilities, and not available to open market purchases. Most timber harvested from NIPF land ownerships is sold to forest products firms for product conversion. Therefore, high levels of NIPF ownership within a parish should indicate a greater amount of timber available on the open market for purchase.

The pulpwood production overlay shown in Figure 15 revealed the current levels of timber harvesting activity in each parish. The actual pulpwood volumes used to construct this overlay were presented in Table 3. The parishes of lowest pulpwood production are in the northwest portion of the study region, while the parishes of highest production are in the east-central area.

Included in most timber availability analyses are the volumes of growing stock and net annual growth of the growing stock. The growing stock overlay that was produced is shown in Figure 16, and the growing stock volumes that were used are shown in Table 11. Growing stock is a measure of the net volume of trees at least 5 inches in diameter at breast height. A 1 foot stump height and a 4 inch merchantable top are assumed (Rosson and Bertelson 1985). Growing stock is a measure of the total merchantable wood fiber resource in the forest, but does not portray wood fiber availability. High volumes of growing stock in a parish do not necessarily imply high availability of wood

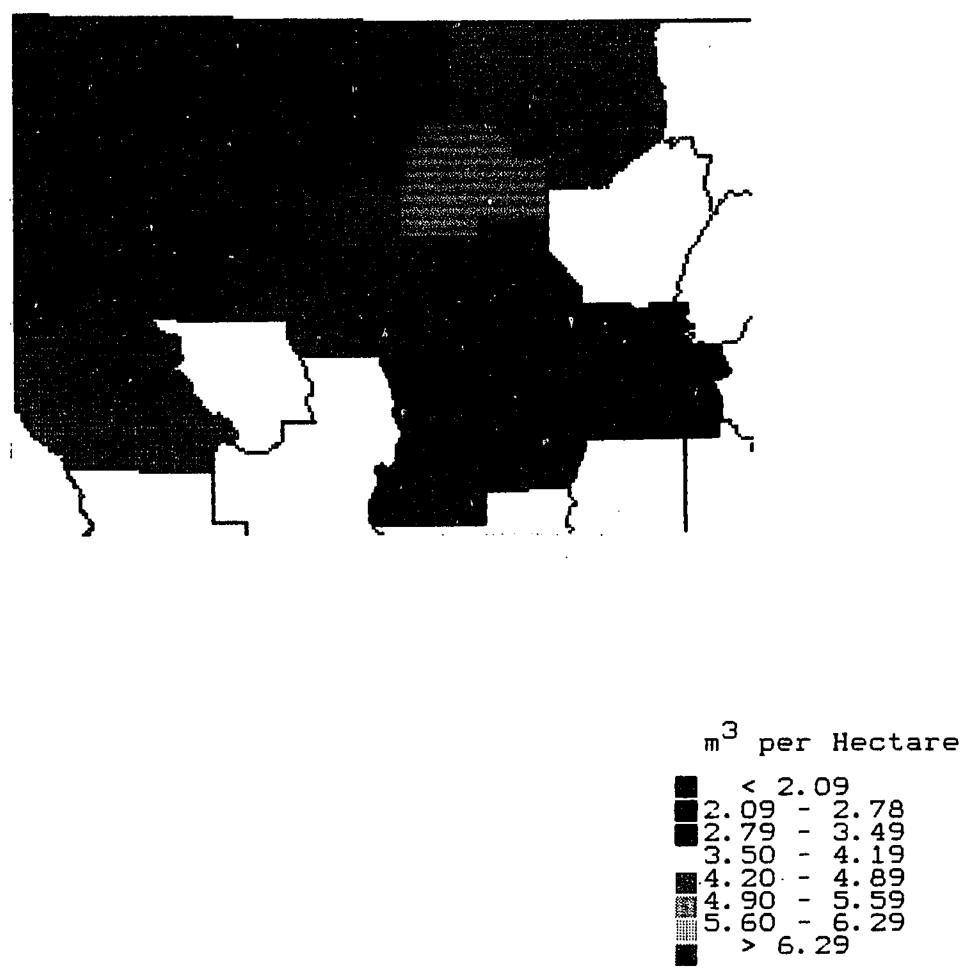


Figure 15. Map file of pulpwood production per hectare by parish.

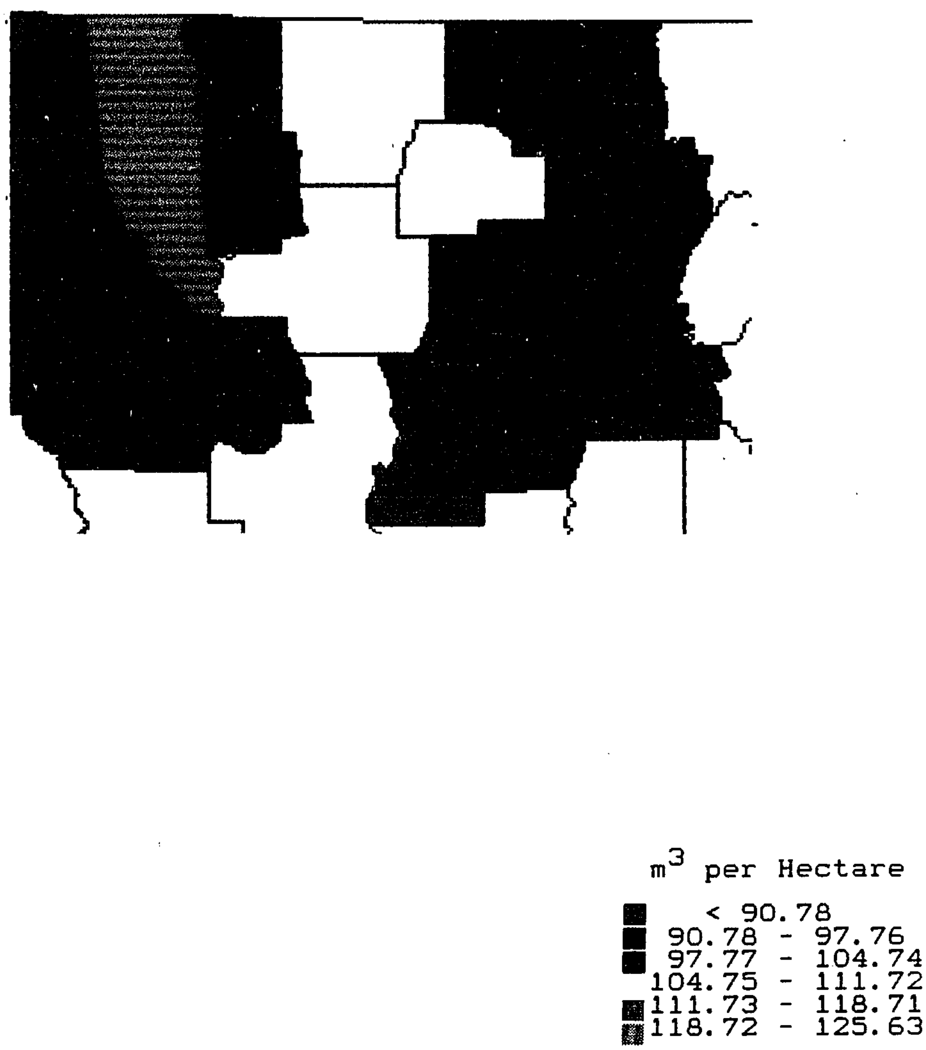


Figure 16. Map file of total growing stock by parish.

Table 11. Growing stock per hectare in northwest Louisiana study parishes.

PARISH	PINE	HARDWOOD	TOTAL
	(m^3)		
Bienville	73.73	35.59	109.32
Bossier	74.46	45.93	120.39
Caddo	44.41	39.34	83.75
Caldwell	40.37	46.34	86.71
Claiborne	69.04	39.90	108.95
De Soto	69.15	28.44	97.59
Jackson	62.51	35.33	97.85
Lincoln	70.89	38.99	109.88
Ouachita	50.42	44.11	94.53
Red River	37.34	41.56	78.90
Union	61.33	36.24	97.57
Webster	58.03	41.72	99.75
Winn	56.14	30.40	86.54
Regional Mean	61.04	37.68	98.72

Source: Rosson and Bertelson (1985).

fiber in that parish. Some of the other factors that influence the availability of wood fiber should be considered. Wood fiber availability was evaluated in this study by comparing reported pulpwood harvest, timberland ownership configuration, growing stock, and average net annual growth.

A wood fiber productivity evaluation based on average net annual growth by parish was made with the overlay shown in Figure 17. This evaluation is also based on average net annual growth of the growing stock and removals by parish in the study region (Table 12). The average net annual growth is defined as the annual net volume increase for each parish between the decennial resource surveys conducted by the USDA Forest Service (Rosson and Bertelson 1985). Average net annual growth volumes were used as an indicator of the relative wood fiber productivity of each parish, and were compared to the total wood removals per acre to evaluate wood growth and removals by parish. As shown in Table 12, there were seven parishes where total wood fiber removals exceeded growth. These excess removals may be the result of a short-term factor, such as excess timber harvested due to recent insect infestations, high age classes which have slower growth rates, or possibly an indication of excessive total wood fiber demand. The parishes of Bienville, Bossier, Caddo, Claiborne, Lincoln, and Webster revealed excess total wood fiber growth over removals, which may be an indication of potential wood fiber availability.

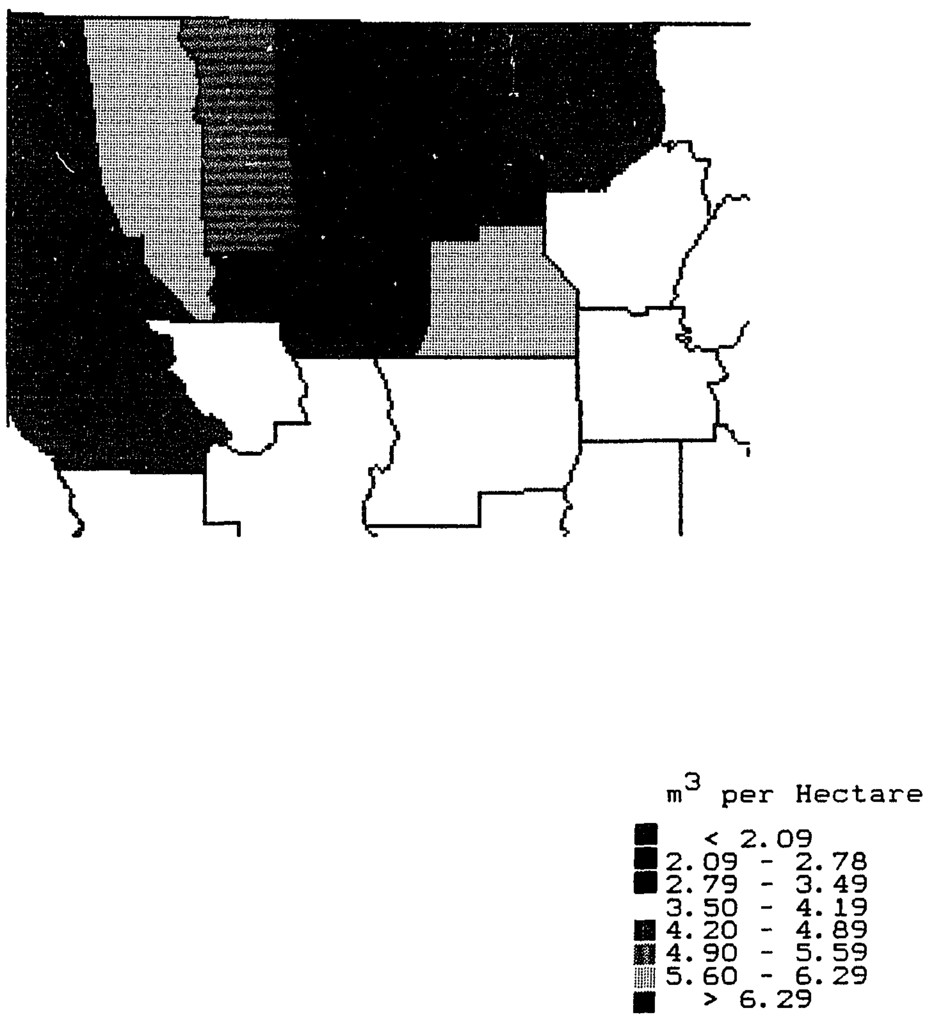


Figure 17. Map file showing average net annual growth of growing stock per hectare in study parishes.

Table 12. Growth and removal of total growing stock, by parish in northwest Louisiana, 1986.

Parish	Growth[1]		Removals[2]		Diff.	
	Pine	Hwd	Pine	Hwd	Pine	Hwd
			(m^3 per hectare)			
Bienville	5.16	2.16	4.73	1.20	0.43	0.96
Bossier	3.84	2.17	2.91	1.12	0.93	1.05
Caddo	2.67	1.68	1.41	0.60	1.26	1.09
Caldwell	2.29	1.90	3.03	1.40	-0.75	0.50
Claiborne	4.64	2.56	3.39	1.13	1.25	1.43
De Soto	3.41	1.33	4.55	1.39	-1.14	-0.06
Jackson	3.69	2.02	6.88	1.91	-3.19	0.11
Lincoln	4.40	1.90	4.55	1.37	-0.16	0.53
Ouachita	2.52	1.43	3.13	1.49	-0.61	-0.06
Red River	1.75	2.42	4.59	1.06	-2.84	1.36
Union	3.32	1.55	4.20	1.70	-0.88	-0.15
Webster	3.24	2.04	2.74	1.04	0.50	1.00
Winn	2.79	1.01	4.28	1.17	-1.49	-0.16
Total	3.49	1.80	3.94	1.29	-0.45	0.51

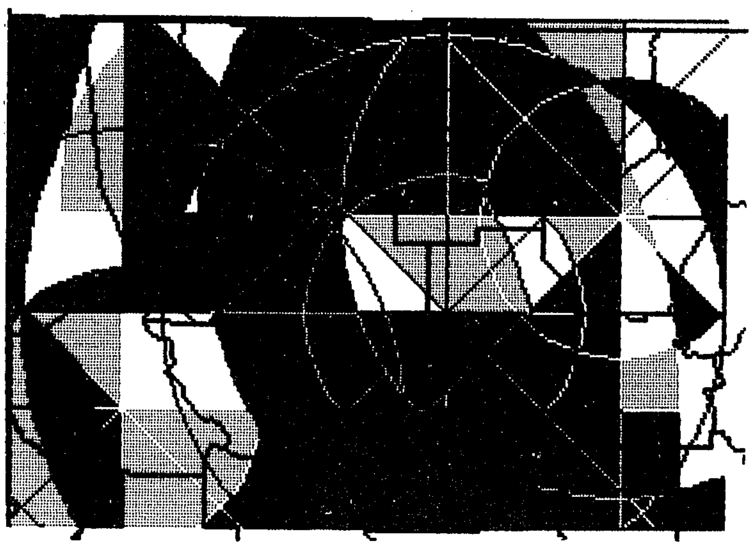
[1] Source: Rosson and Bertelson (1985).

[2] Source: La. Office of Forestry (1987).

Pulpmill Total Demand

Circular procurement zones. The overlay of total pulpmill demand for pulpwood in the blocked study region had 42 different demand levels, determined by the additive intersection of the 18 demand attribute values attached to the procurement segments of each pulpmill location. Evaluation of the histogram for this overlay suggested three classes of pulpwood demand which were classified as high, medium, and low (Figure 18, Table 13). The areas have been adjusted for image noise produced from the procurement segment boundary lines within each respondent's procurement area. The color pattern for this overlay is of increasing color intensity for increasing demands within each demand class. The total demand area of 3.203 million hectares (7.912 million acres) exceeded the 2.433 million hectares (6.011 million acres) of the 13 parish study region, because areas outside of the study region were included in the raster analysis. These areas were eliminated when demand was later evaluated on a parish basis.

To determine the spatial location of each demand class, the class boundaries were digitized from the graphics monitor. These class boundaries were then overlaid on the study region to determine the area by demand class within each parish (Figures 19 - 21). Total demand area, by parish, was an underestimate by 3.97 percent of the parish acreage as reported by the USDA Forest Service, Forest Survey Unit (Rossen and Bertelson 1985).



Demand Levels

Low demand

Medium Demand

High Demand

Figure 18. Overlay of pulpmill total pulpwood demand.

Table 13. Area of demand classification for pulpmill total pulpwood demand in northwest Louisiana study region.

Demand Class	Demand Level	Area (hectares)	Percent
Low	1 - 19	572,077	12.8
Medium	20 - 29	1,114,280	34.1
High	29 - 48	1,517,095	53.1
Total		3,203,452	100.0

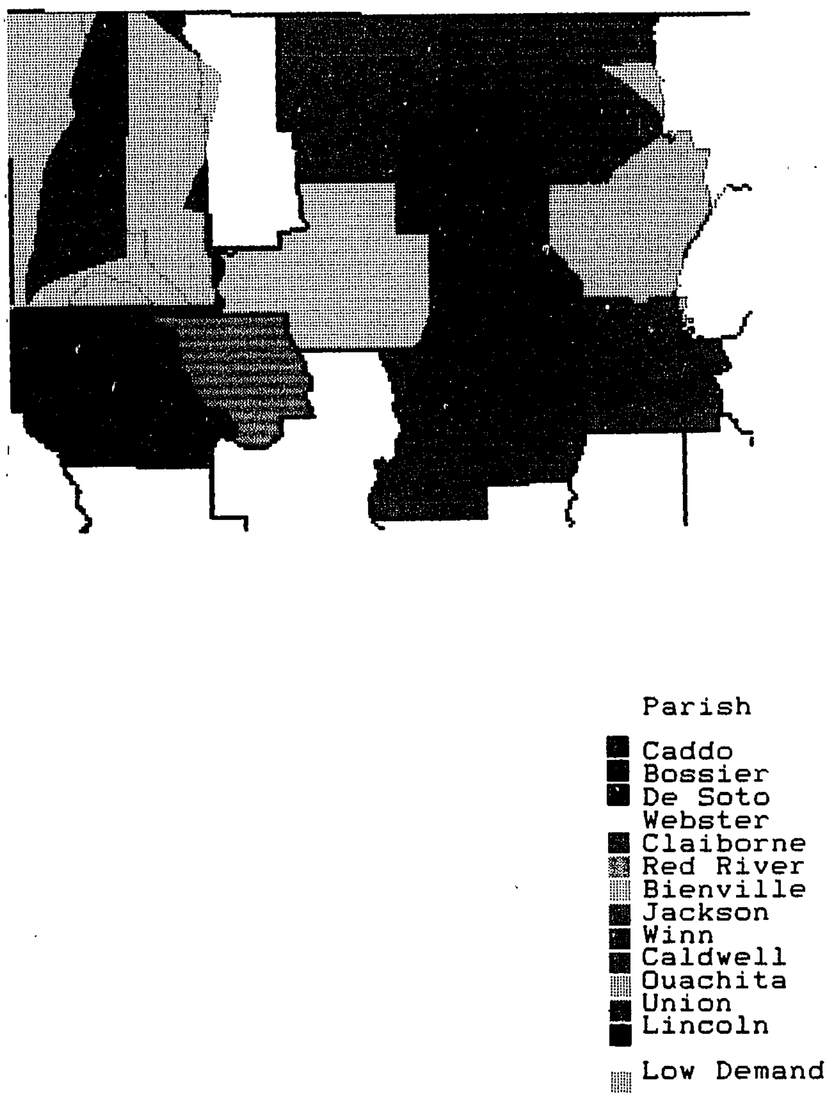


Figure 19. Overlay of areas of low total pulpwood demand by northwest Louisiana region pulpmills.

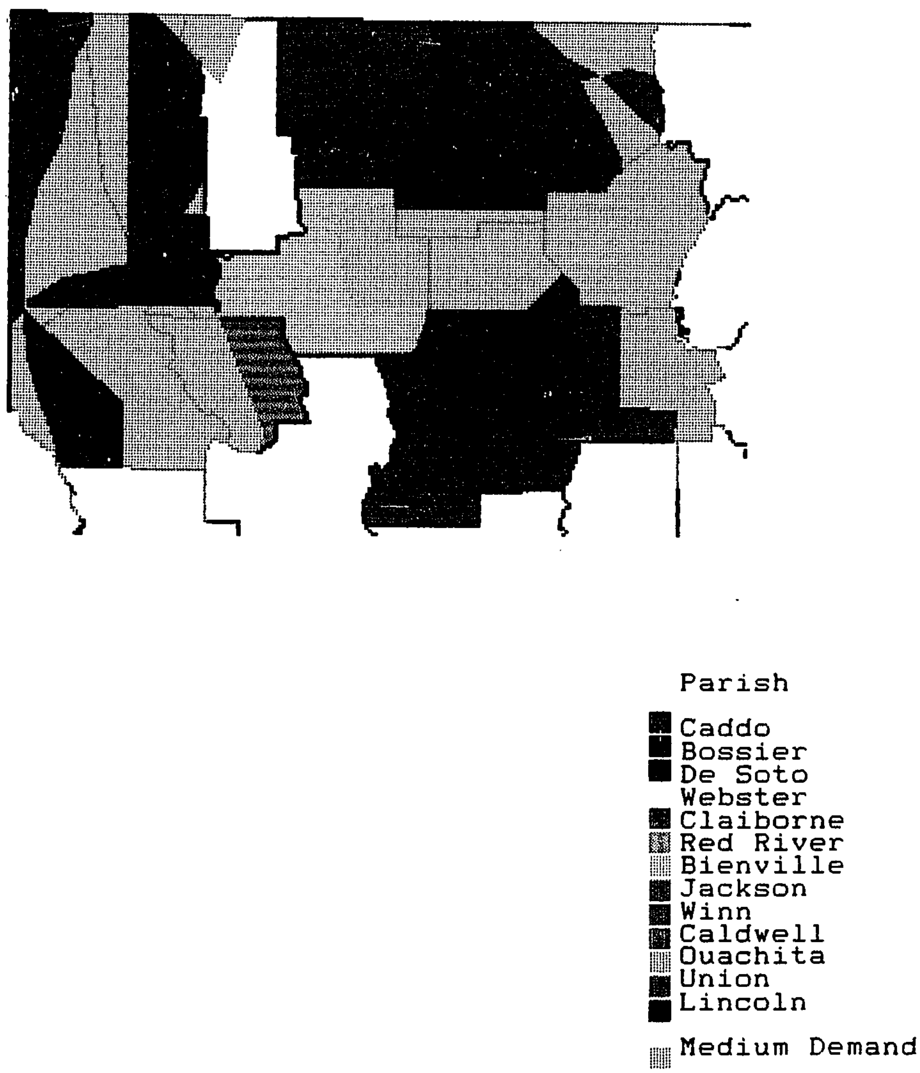


Figure 20. Overlay of medium total pulpwood demand by northwest Louisiana region pulpmills.

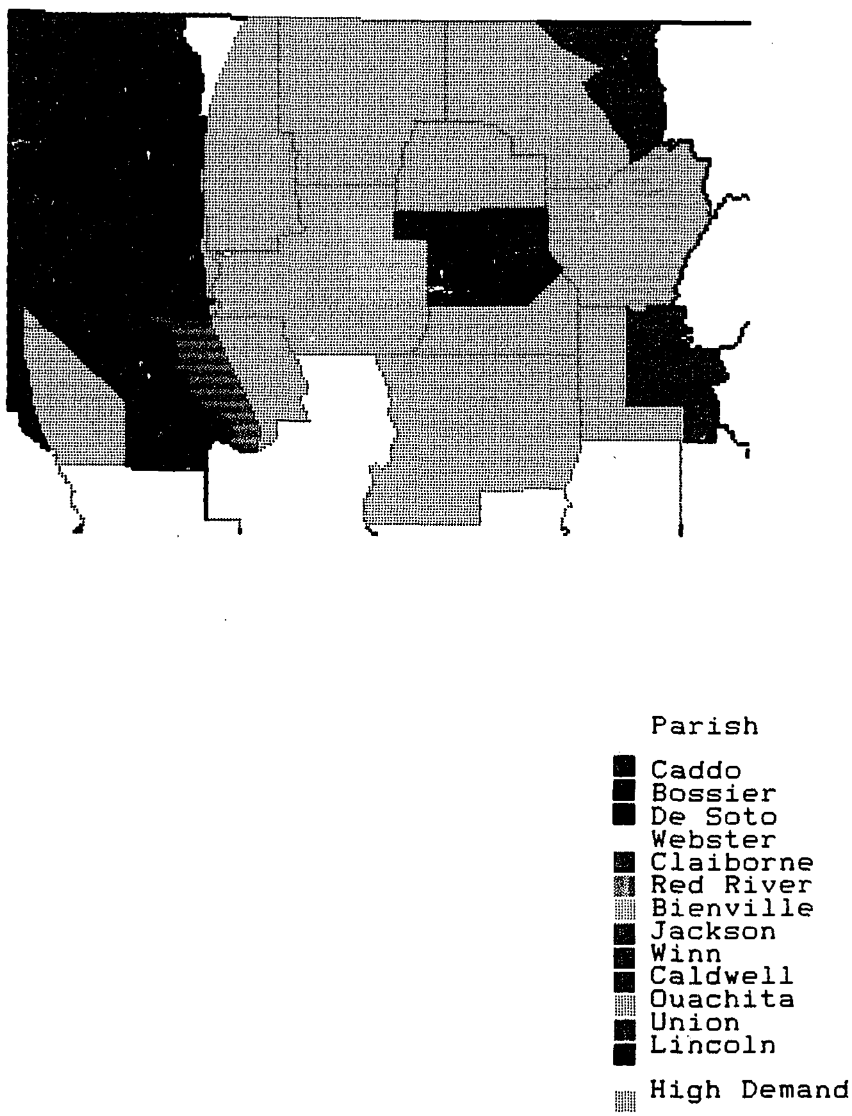


Figure 21. Overlay of high total pulpwood demand by northwest Louisiana region pulpmills.

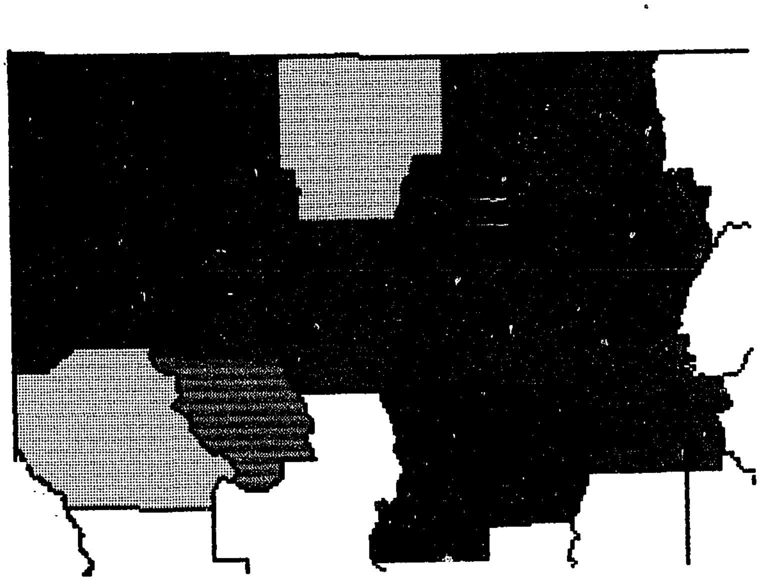
The majority, 85 percent, of the difference is due to the width of the parish and demand level border lines produced on the graphics monitor. The remaining difference was attributed to spatial resolution and map digitization error. Bossier and Caddo parishes contained the largest area of low pulpwood demand, while the parishes in the central portion of the study region maintained the highest levels of demand by the pulpmills for the pulpwood resource (Table 14). The edge effects of the study region did not contribute significantly to the demand level produced, as the overlay of procurement areas of the pulpmills encompassed the entire study region.

Other variables which contributed to the pulpwood procurement environment were evaluated through the use of cartographic modeling techniques to determine whether to emphasize future procurement efforts in these areas of low competition. A large portion of Caddo parish had a high level of NIPF ownership, 95 percent, and an area of low pulpwood demand that coincided with a region in De Soto parish of a slightly lower NIPF ownership of 81 percent (Figure 22, Table 15). In addition, neighboring Bossier parish, which had a 69 percent NIPF ownership, also had an intersection of these two attributes.

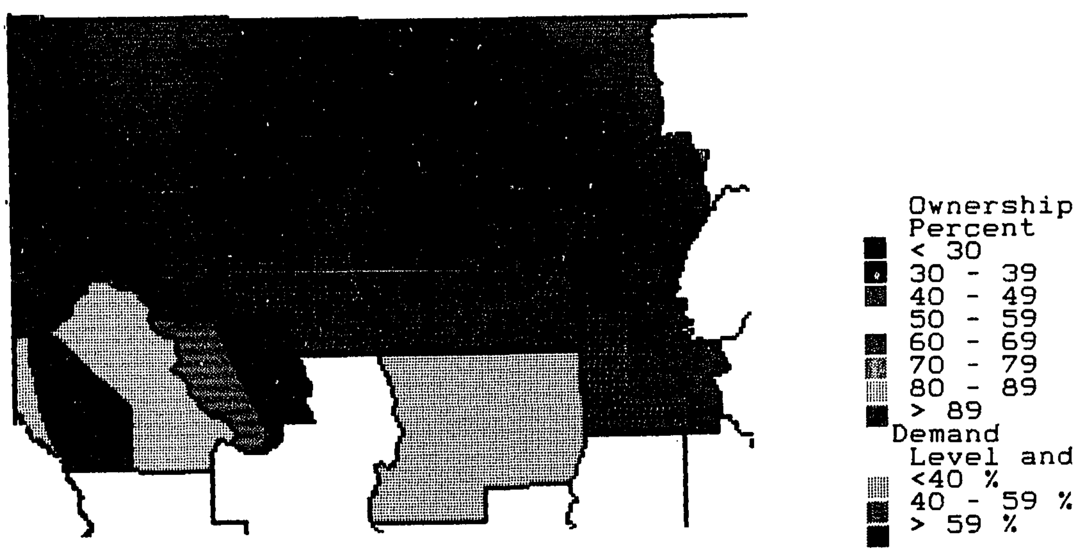
Forty-seven percent of the high pulpwood demand areas was in parishes with less than 30 percent forest industry ownership. Thirty-six percent of the high demand area was in parishes composed of greater than 50 percent forest

Table 14. Acreage calculation of demand levels of total pulpwood demands of northwest Louisiana region pulpmills, by parish.

	Demand Level Acreage (hectares)			
Parish	Low	Medium	High	Total
Bienville	230	51,735	158,115	210,080
Bossier	158,421	48,445	6,352	213,218
Caddo	128,727	104,237	2,066	235,030
Caldwell	1,913	57,654	64,364	123,931
Claiborne			192,478	192,478
De Soto	13,393	131,482	78,828	223,703
Jackson		71,364	69,108	140,472
Lincoln		20,587	91,762	112,349
Ouachita	8,801	97,962	50,817	157,580
Red River		49,517	55,868	105,385
Union	12,092	59,925	158,115	230,132
Webster	7,806	16,225	134,543	158,574
Winn			237,632	237,632
Total	331,383	709,133	1,300,048	2,340,564



a.   Low pulpmill demand.



b.   High pulpmill demand

Figure 22. Pulpmill demand classes overlaid on NIPF ownership percentage.

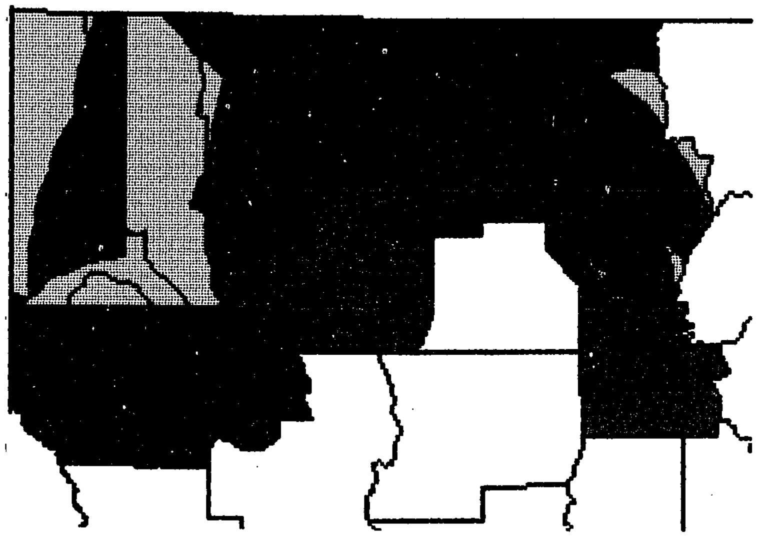
Table 15. Area of timberland ownership percentage by demand level of pulpmills in northwest Louisiana.

	Demand Level (hectares)	
Ownership Percent	High	Low
NIPF < 30	237,632	
30 - 39		
40 - 49	291,586	2,143
50 - 59		
60 - 69	349,827	187,197
70 - 79	55,869	
80 - 90	271,306	13,393
> 90	93,828	128,650
Total	1,300,048	331,383
For Ind < 30	612,716	317,149
30 - 39	158,114	12,092
40 - 49	64,362	1,913
50 - 59	306,741	
60 - 69	158,115	229
70 - 79		
80 - 89		
> 90		
Total	1,300,048	331,383

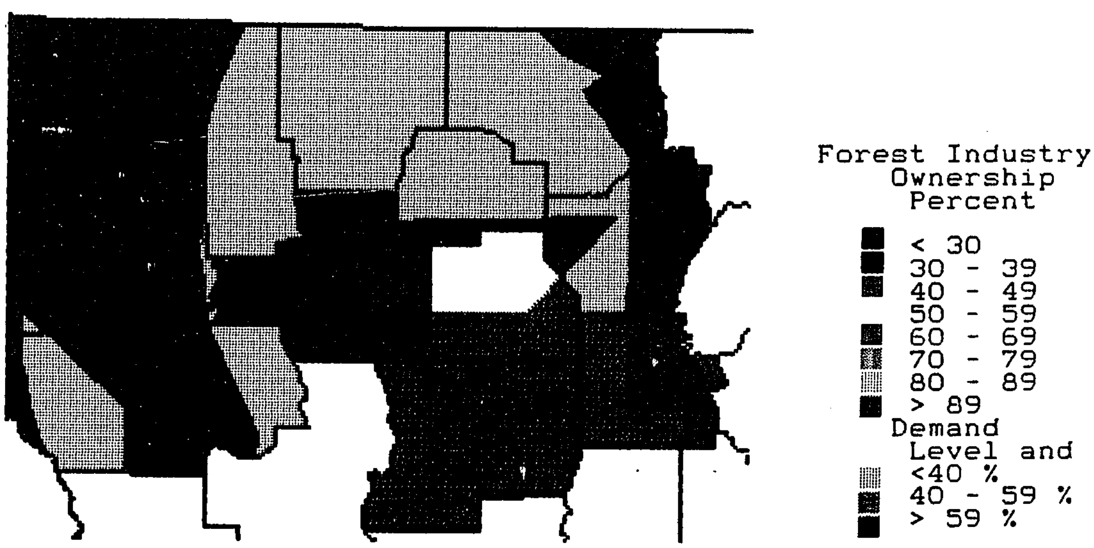
industry ownership (Figure 23, Table 15). There were virtually no areas of low demand in conjunction with forest industry ownership greater than 50 percent. This suggests a relatively high level of wood fiber production on these lands, and a low level of wood availability to the open market. Ninty-nine percent of the low demand area occurred within parishes of greater than 50 percent NIPF ownership, and 41 percent of the area of high demand was within parishes of less than 50 percent NIPF ownership, as would be expected (Table 15).

A wood procurement forester competing on the open timber market for pulpwood would be interested in evaluating timberland areas of low demand levels and high NIPF ownership, all other procurement factors being equal. Such a potential area appears to be in Caddo and Bossier parishes.

Areas of low pulpwood demand were predominantly in the parishes of lowest pulpwood removals per hectare. There were no areas of low demand with pulpwood removal levels greater than 4.30 cubic meters per hectare (61.5 cubic feet per acre). The average pulpwood removal per hectare in the study region was 3.83 cubic meters per hectare (54.7 cubic feet per acre), with the areas of high demand distributed over the entire range of removals per hectare (Figure 24, Table 16). Assuming that the pulpwood resource is present as growing stock in these low demand/low removal areas,

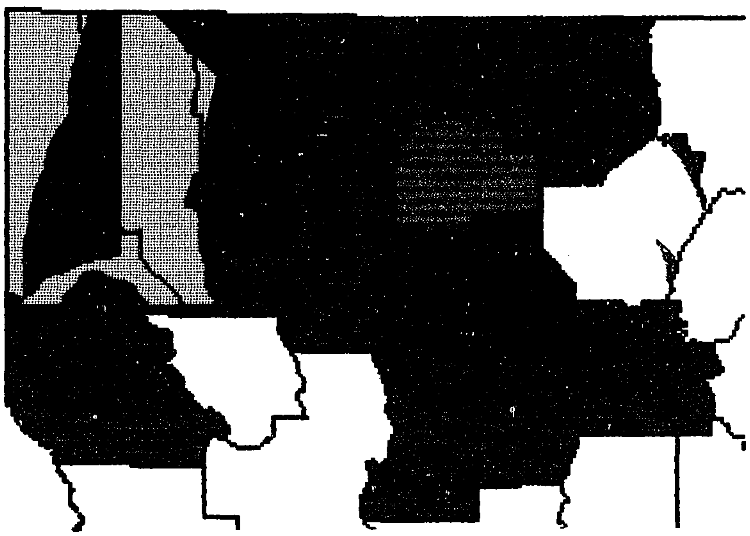


a. Low pulpmill demand.

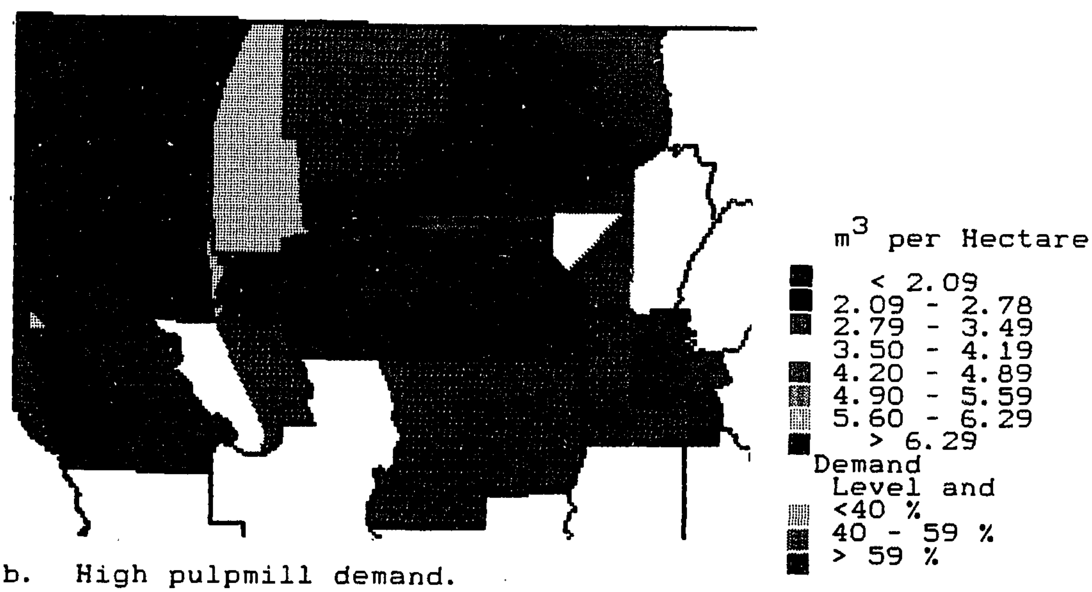


b. High pulpmill demand.

Figure 23. Demand classes overlaid on forest industry ownership percentage.



a. Low pulpmill demand.



b. High pulpmill demand.

Figure 24. Pulpmill demand levels overlaid on reported total pulpwood removals.

Table 16. Areas of average total pulpwood removals from northwest Louisiana timberland by demand class.

Removals (m^3 per ha.)	Demand Level (hectares) High	Low
< 2.10	2,066	128,650
2.10 - 2.73	140,896	166,304
2.74 - 3.43	494,474	1,913
3.44 - 4.13	106,686	8,801
4.14 - 4.83	395,058	25,715
4.84 - 5.53	91,762	
5.54 - 6.23		
> 6.23	69,108	
Total	1,300,050	331,383

there is potential for a greater wood procurement effort in these areas of low demand/low removals. If growing stock is not sufficient, the low demand/low removal is possibly due to insufficient pulpwood volume per forested hectare to attract the wood procurement foresters.

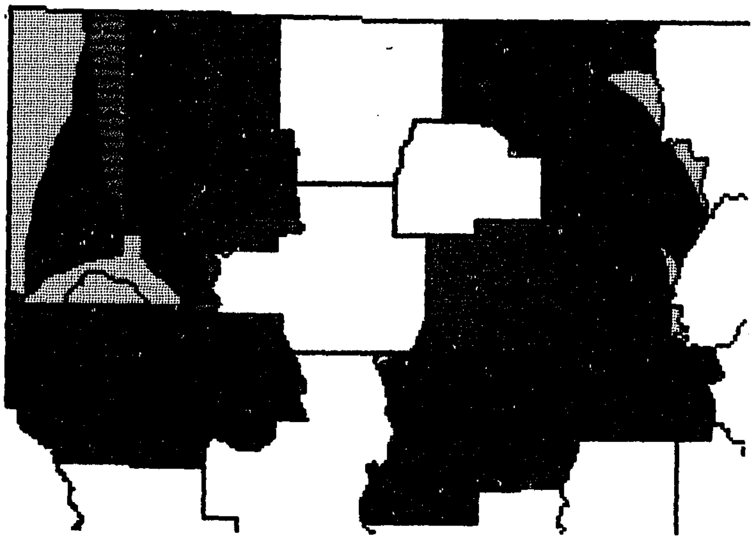
Growing stock volumes were divided into six classes (Table 17). The areas of high pulpwood demand were almost entirely in the lowest four growing stock levels (Figure 25). There were virtually no areas of high pulpmill demand in Bossier parish. In Bossier parish there was an intersection of low levels of pulpwood demand in conjunction with the highest average growing stock per hectare in the study region.

The parishes with the highest growth rates were Bienville, Claiborne, and Lincoln. These parishes were almost entirely within the region of highest demand (Figure 26); they also ranked as three of the top four parishes in total growing stock levels (Figure 16). The 158,498 hectare region of low demand and average annual growth of 6.03 cubic meters per hectare located in Bossier parish is of special interest (Table 18).

Bossier parish is the most likely parish within the study region to be further explored for future emphasis of wood procurement efforts by the pulpmill procurement managers (Table 19). Bossier parish contained the largest area of low demand, and also the smallest area of high demand. This parish has a relatively high NIPF timberland

Table 17. Areas of average total growing stock in northwest Louisiana by demand class.

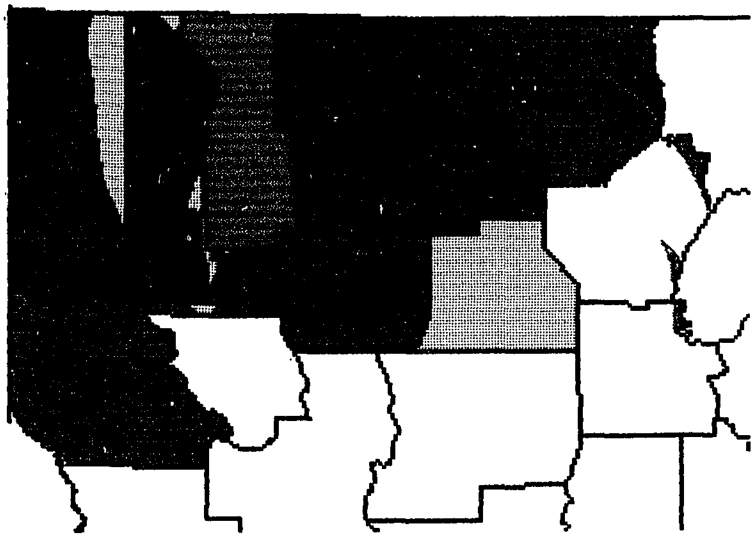
Growing Stock (m^3 per ha.)	Demand Level (hectares) High	Low
< 91.00	359,930	130,564
91.00 - 97.92	287,761	34,286
97.93 - 104.92	203,652	7,806
104.93 - 111.92	442,355	229
111.93 - 118.92		
118.93 - 125.92	6,352	158,498
Total	1,300,050	331,383



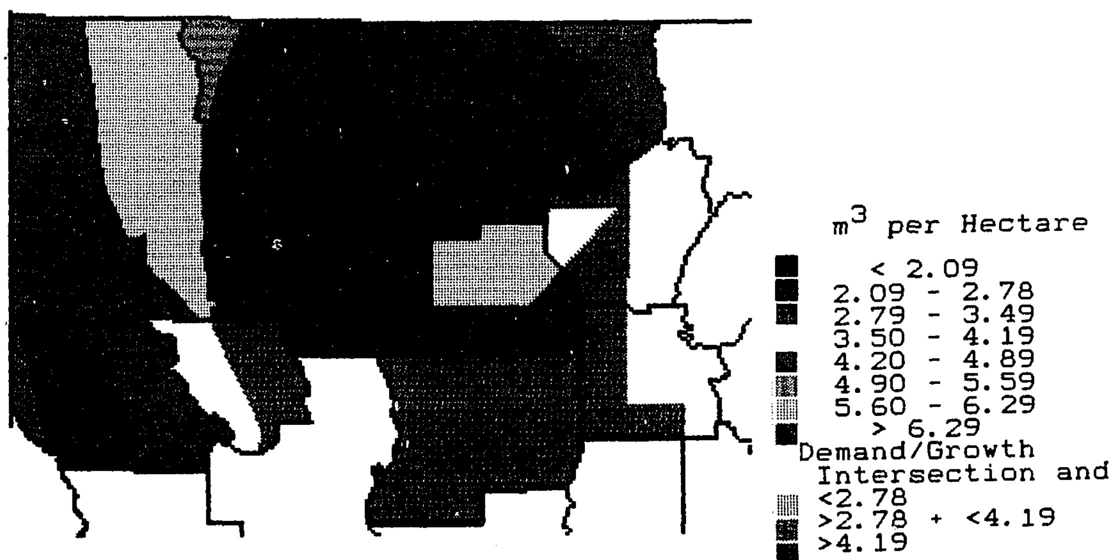
a. Low pulpmill demand.

b. High pulpmill demand.

Figure 25. Pulpmill demand levels overlaid on average total growing stock.



a. Low pulpmill demand



b. High pulpmill demand

Figure 26. Average net annual growth of growing stock and total pulpmill demand intersection.

Table 18. Areas of average annual growth of total growing stock in northwest Louisiana by demand class.

Growth (m^3 per ha.)	Demand Level (hectares)	
	High	Low
< 2.09		
2.09 - 2.73		
2.74 - 2.49		
3.50 - 4.19	408,681	10,714
4.20 - 4.89	239,010	154,136
4.90 - 5.59	134,543	7,806
5.60 - 6.29	75,461	158,498
> 6.29	442,355	230
Total	1,300,050	331,384

Table 19. Rating of key wood procurement factors for northwest Louisiana pulpmill total demand.

Parish	Percent of Low Demand Area	Percent NIPF Ownership	Removals/ Growth (m^3/ha)	[1]Rank of Grow Stk
Bienville	0.1	40.00	80.95	11
Bossier	74.3	69.13	67.08	13
Caddo	54.8	94.74	46.02	2
Caldwell	1.5	39.55	105.96	4
Claiborne	0.0	85.22	62.76	10
De Soto	6.0	81.25	125.36	7
Jackson	0.0	42.86	153.84	8
Lincoln	0.0	94.86	94.08	12
Ouachita	5.6	69.46	117.02	5
Red River	0.0	73.08	135.53	1
Union	5.2	61.27	121.01	6
Webster	4.9	67.26	71.51	9
Winn	0.0	26.91	143.57	3

[1] Higher values indicate higher levels of growing stock.

ownership, of 69.13 percent, and is also in the lowest forest industry ownership percentage class, less than 30 percent. Bossier parish is in the second lowest removal class of 2.09 to 2.78 cubic meters per hectare, and has a removal/growth percentage of 67.08, the third lowest of all parishes in the study region. In addition, this parish had the highest level of total growing stock, 118.72 to 125.63 cubic meters per hectare, and the highest average annual growth per hectare within parishes with low total pulpwood demand.

A second parish that is a likely candidate for further procurement effort is Caddo parish. This parish is second in lowest demand area, and has the highest NIPF ownership percentage within the study region. Although Caddo parish was ranked very low in volume of total growing stock per hectare, it has the lowest removal/growth percentage of all parishes within the region.

These two parishes contain the urban areas of Shreveport and Bossier City; but they should be investigated further in the field, and if warranted, a shift of emphasis from the more competitive parishes of Winn, Claiborne, and Bienville to the northwest portion of the study region might be in order.

Highway distance isoline comparison. Procurement zones based on highway distance isolines were produced to provide an alternative approach to the construction of procurement zones. An overlay depicting four highway distance isolines at 40.2 kilometer (25 mile) intervals from the mill location was prepared for each pulpmill in the region. With the eight procurement corridor and four distance zones, there were 32 procurement segments. Total pulpwood demand volumes were assigned based on questionnaire responses (Figure 27). The accuracy of assigning volumes in this manner is unknown, but to accurately delineate pulpwood demand within the irregularly shaped isoline segments is a practical impossibility. An overlay of total pulpmill demand using highway isoline procurement segments was prepared (Figure 28), and the blocked regional demand classification was calculated (Table 20). The same demand class intervals were used as for the circular procurement system to allow uniformity of comparison.

Compared to the areas of the circular von Thunen procurement zone delineation (Table 13), there was a marked difference for all demand classes. The isoline system has a 98 percent larger area than the circular system for the low demand class, 17 percent area reduction of the medium demand class, and a 24 percent area reduction of the high demand class. The effect of highway distance isolines was to reduce the area of each of the procurement segments in an irregular manner that depended on the highway network in

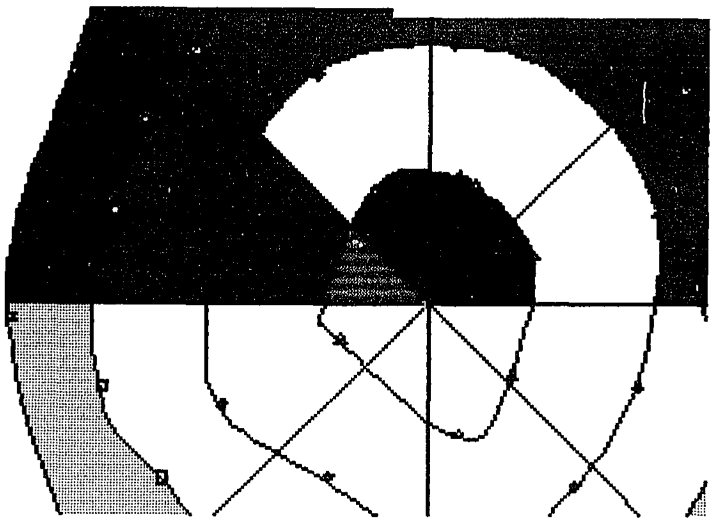


Figure 27. Interpretation of an example respondent procurement zone based on a highway distance isoline (see Table 10 for legend).

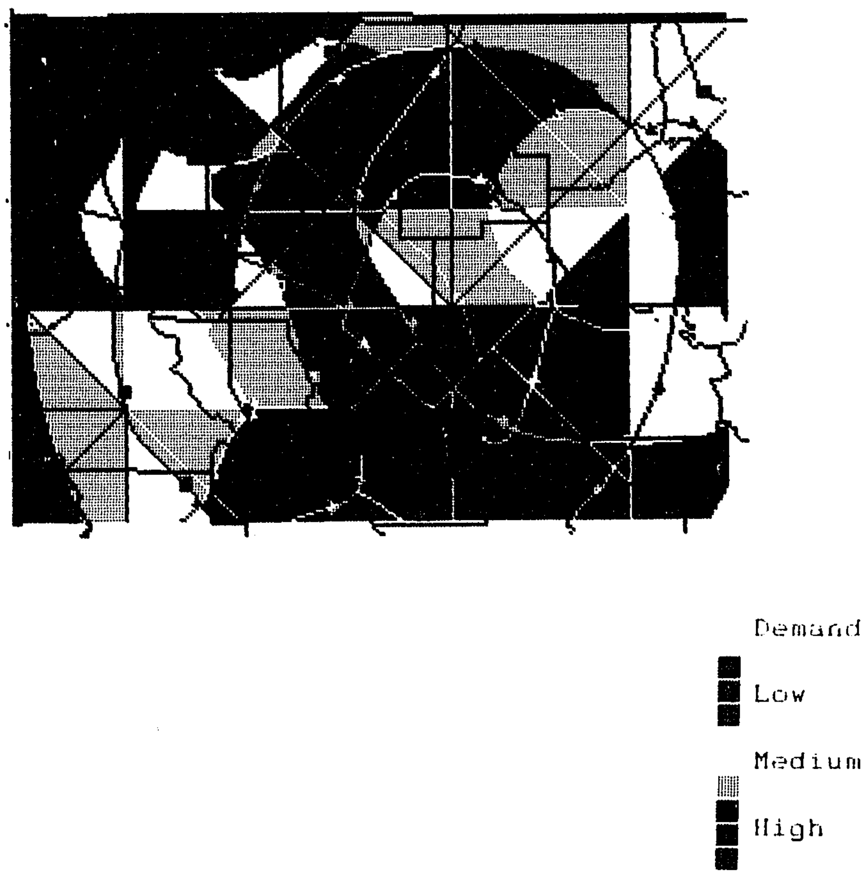


Figure 28. Overlay of pulpmill total pulpwood demand based on a highway distance isoline.

Table 20. Area of demand classification for northwest Louisiana pulpmill total pulpwood demand based on highway isoline distances in blocked study region.

Demand Classification	Demand Class	Area (hectares)	Percent
Low	1 - 19	1,132,490	35.3
Medium	20 - 29	922,304	28.8
High	30 - 48	1,148,658	35.9
Total		3,203,452	100.0

each respondent's procurement area. A possible explanation for the large increase in the area of low demand is that segments of low demand that were further from the respondent's procurement center, and outside of the study region, are now considered within the study region and are included in the demand area calculations. The area of all procurement segments have also been reduced. Thus, those segments that contained high levels of pulpwood demand now encompass a smaller area.

With highway distance isolines, an area of low demand was also found in the northwest portion of the study region (Figure 28). The general location of the areas of low, medium, and high demand are quite similar to those represented by the circular von Thunen system (Figure 18). The low demand area is heavily concentrated in the northwest portion of the study region, and the parishes of Caddo and Bossier represent an almost exclusive area of low demand. The area of high pulpmill demand isolines is still concentrated in the central portion of the study region.

All parishes showed a reduction in the area encompassed by high demand, except for Winn parish, which retained a 100 percent area coverage of high pulpwood demand by the pulpmills (Table 21). The area of the three levels of demand appeared to be more uniformly distributed in this approach to procurement zone delineation, but there is no feasible means of comparing the accuracy of the isoline and circular procurement zone delineations.

Table 21. Area calculation of demand levels as represented by highway isoline distances in northwest Louisiana, by parish.

Parish	Demand Level (hectares)			
	Low	Medium	High	Total
Bienville	23,419	40,408	146,253	210,080
Bossier	207,019	6,199		213,218
Caddo	228,066	6,964		235,030
Caldwell	9,107	62,706	52,118	123,931
Claiborne	13,470	34,516	144,492	192,478
De Soto	77,297	146,330	76	223,703
Jackson		75,879	64,593	140,472
Lincoln		44,465	67,884	112,349
Ouachita	61,914	67,655	28,011	157,580
Red River		90,232	15,153	105,385
Union	2,832	145,946	81,354	230,132
Webster	81,048	21,428	56,098	158,574
Winn			237,632	237,632
Total	704,172	742,728	893,664	2,340,564

Pulpmill Pine Demand

Pine pulpwood usage by the pulpmills within the study region accounted for 71.3 percent of the pulpmill total wood usage. Pine procurement zones were not reported separately by the respondents, but were determined as a percentage of the total pulpwood procured. This volume was allocated to each circular procurement zone based on the procurement manager's perception of the total procurement area. The overlay of pine pulpwood demand by the pulpmills (Figure 29), resulted in a total of 40 demand levels from the additive effects of the intersection of the pine pulpwood procurement requirements of the three pulpmills. A histogram analysis of the pine pulpwood demand overlay was used to produce three demand classes: level 18 and below for low demand, level 19 to 30 for medium demand, and 31 and above for high demand.

The parishes of Bossier and Caddo in the northwestern portion of the study region encompassed the greatest portion of the low demand area, while Winn and Claiborne parishes had the greatest area of high demand levels (Table 22). This parish ranking is similar to the total pulpwood demand allocation (Table 14). All parishes tended to measure larger areas in the middle demand level as compared to the total pulpwood demand allocation.

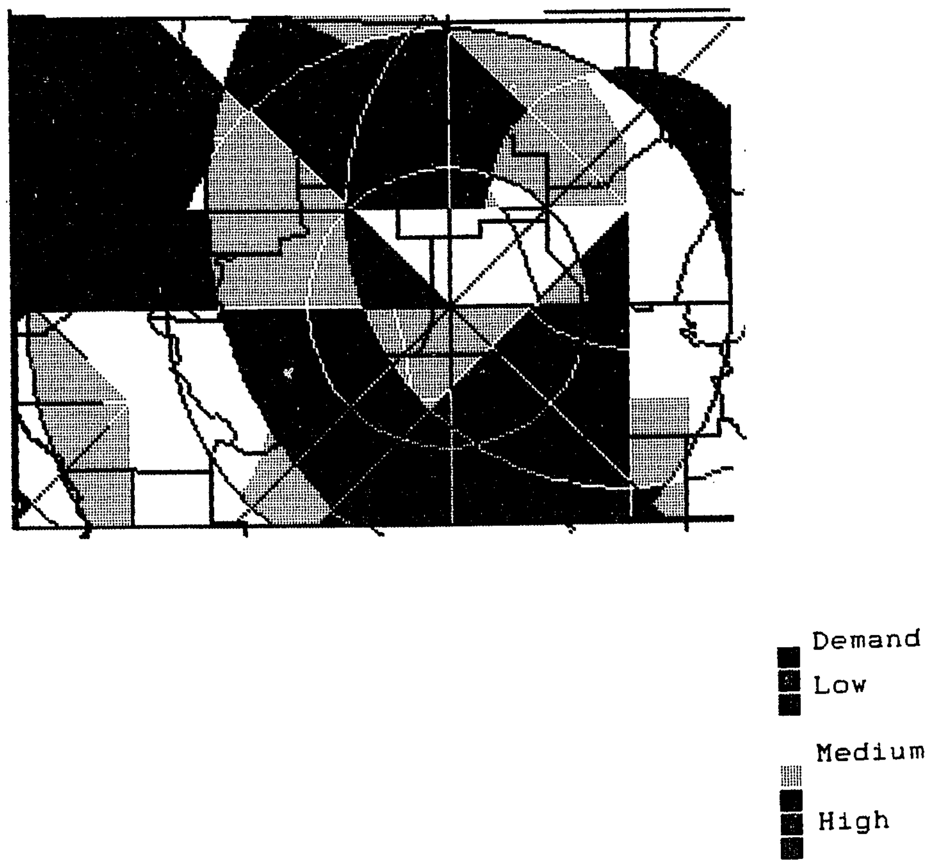


Figure 29. Overlay of pine procurement segments at pulpmills in northwest Louisiana.

Table 22. Pine pulpwood demand levels at pulpmills in northwest Louisiana region, by parish.

Parish	Demand Level (hectares)			
	Low	Medium	High	Total
Bienville	40,792	119,313	49,975	210,080
Bossier	203,040	10,102	76	213,218
Caddo	225,999	9,031		235,030
Caldwell		73,420	50,511	123,931
Claiborne		17,143	175,335	192,478
De Soto	14,235	209,468		223,703
Jackson	1,607	111,313	27,552	140,472
Lincoln		46,302	66,047	112,349
Ouachita	6,199	125,972	25,409	157,580
Red River		54,721	50,664	105,385
Union	13,852	179,009	37,271	230,132
Webster	8,954	112,961	36,659	158,574
Winn		22,118	215,514	237,632
Total	514,678	1,090,873	735,013	2,340,564

The overlay of ownership and pine pulpwood demand levels was used to calculate ownership/demand area (Table 23). In the classification of low pine demand, 91.7 percent of the low demand was in parishes with NIPF land ownership of greater than 60 percent. Low pine demand level overlaid on forest industry ownership percentage revealed only 10.9 percent of the area of low demand in parishes with forest industry timberland ownership percentages greater than 30 percent.

The analysis of the intersection of high levels of pine pulpwood demand and NIPF ownership percentage revealed 46.7 percent of the high demand in parishes with NIPF ownership of less than 60 percent. The high pine demand area overlaid on forest industry ownership revealed 51.8 percent of the high demand area to intersect with forest industry timberland ownership of greater than 30 percent. Of the 13 study parishes, five had forest industry timberland ownership percentages greater than 30 percent. These five parishes accounted for 46.7 percent of the high demand area, with the majority of the acreage in Winn and Bienville parishes. Thus, there may have been more intensive timber demand and harvesting activities on forest industry timberland than NIPF timberland, and possibly a greater reliance by the pulpmills on forest industry lands for pine pulpwood.

Table 23. Pine pulpwood demand levels at northwest Louisiana pulpmills, by timberland ownership.

	Demand Level (hectares)	
Ownership Percent	High	Low
NIPF < 30	215,514	
30 - 39		42,399
40 - 49	128,038	
50 - 59		
60 - 69	99,415	232,122
70 - 79	50,664	
80 - 90	175,335	14,235
> 90	66,047	225,922
Total	735,013	514,678
For Ind < 30	354,190	458,427
30 - 39	37,271	13,852
40 - 49	50,511	
50 - 59	243,066	1,607
60 - 69	49,975	40,792
70 - 79		
80 - 89		
> 90		
Total	735,013	514,678

The portrayal of pine pulpwood removal was produced with the same volume level classification as total removals. The lowest removal level, less than 2.10 cubic meters per hectare, represented 85.1 percent of the area of low pine pulpwood demand (Table 24). The high percentage of low demand and low removals reinforces the geographic location of the procurement zone perception perceived by the pulpmill procurement managers. The median pine pulpwood removal was 2.70 cubic meters per hectare. Although one would expect the area of high demand to occur in areas of high removals, only 19.5 percent of the high pine demand area was in the removal class greater than the median pine pulpwood removal per hectare.

The area of pine pulpwood demand levels was overlaid on pine growing stock (Table 25). Pine growing stock was divided into eight classes. The area of low demand was distributed over the highest four classes; the overlay of high demand tended to be in the highest two growing stock classes, with 82.7 percent of the area of high demand in these two classes. This area was primarily in Claiborne and Winn parishes. The parish containing the highest level of pine growing stock was Bossier parish, which was almost entirely within the region of low demand.

The area of intersection of pine demand levels and annual growth of pine growing stock is shown in Table 26. There was no appearance of a trend of demand emphasis towards a single growth level, as both high and low demand

Table 24. Pine pulpwood demand levels at northwest Louisiana pulpmills, by level of pine pulpwood removals.

Removals (m^3 per ha.)	Demand Level (hectares) High	Low
< 2.10	87,247	437,993
2.10 - 2.73	504,193	20,051
2.74 - 3.43	49,975	55,027
3.44 - 4.13	66,047	
4.14 - 4.83		
4.84 - 5.53		
5.54 - 6.23	27,551	1,607
> 6.23		
Total	735,013	514,678

Table 25. Area of low pine demand at northwest Louisiana pulpmills and pine growing stock.

Growing Stock (m^3 per ha.)		Demand Level (hectares) High	Low
< 20.95			
20.95	27.92		
27.93	34.91		
34.92	41.89	101,175	
41.90	48.87		225,999
48.88	55.86	25,409	6,199
55.87	62.85	316,996	24,414
> 62.85		291,434	258,066
Total		735,014	514,678

Table 26. Area of demand of pine pulpwood at northwest Louisiana pulpmills and average annual growth of pine growing stock.

		Demand Level (hectares)	
Growth (m^3 per ha.)		High	Low
< 2.09		50,664	
2.09	2.72	291,434	232,198
2.79	3.42	73,930	37,042
3.49	4.12	27,628	204,647
4.19	4.82	241,382	
4.89	5.52	49,975	40,791
5.59	6.22		
> 6.28			
Total		735,013	514,678

areas were distributed over the range of growing stock levels.

A comparison of procurement factors for pine pulpwood in the study region is shown in Table 27. The area of the study region that appears most likely for more intensive pine pulpwood procurement efforts by the pulpmill procurement foresters should be Bossier parish. The region of low pine pulpwood demand in Bossier parish encompassed 95.23 percent of the parish timberland area. Although, this parish did not have the lowest level of removals to growth of pine growing stock, Bossier parish was ranked highest in terms of pine growing stock per hectare of all of the parishes within the study region. In addition, NIPF ownership was relatively high, and forest industry ownership percentage was quite low.

The parish in the area of high demand with the least desirable conditions for pulpwood procurement was Red River parish. The level of pine growing stock and average annual growth on the growing stock in this parish was the lowest per hectare of all parishes in the study region. The ratio of removals to growth was 2.62:1, and excessive harvesting in conjunction with the high level of demand was indicated. In addition, Red River parish had no areas of low pine pulpwood demand.

Table 27. Rating of key wood procurement factors for northwest Louisiana pulpmill pine demand.

Parish	Percent of Low Demand Area	Percent NIPF Ownership	Removals/ Growth (m^3/ha)	[1]Rank of Grow Stk
Bienville	19.4	40.00	91.61	12
Bossier	95.2	69.13	75.76	13
Caddo	96.2	94.74	52.74	3
Caldwell	0.0	39.55	132.67	2
Claiborne	0.0	85.22	73.09	9
De Soto	6.4	81.25	133.52	10
Jackson	1.1	42.86	186.43	8
Lincoln	0.0	94.86	103.53	11
Ouachita	3.9	69.46	124.29	4
Red River	0.0	73.08	262.05	1
Union	6.0	61.27	126.36	7
Webster	5.6	67.26	84.56	6
Winn	0.0	26.91	153.55	5

[1] Higher values indicate higher levels of growing stock per hectare.

Pulpmill Hardwood Demand

The analysis of hardwood pulpwood demand at the pulpmills in the study region produced 28 distinct levels of demand, the fewest of any analysis. This was expected, as hardwood pulpwood requirements were only 28.7 percent of the total pulpmill demand. The hardwood demand overlay was differentiated into three demand classifications; low demand encompassed demand classes 1 to 12, medium demand was in classes 13 to 22, and high demand ranged from 23 to 28 (Figure 30). The majority of the study region appears within the low hardwood classification.

The area of high hardwood demand comprised only 7.6 percent of the study region, and was contained almost exclusively in the parishes of Winn and Claiborne. The area of low hardwood demand comprised 76.8 percent of the study area. All parishes within the study region contained areas of low hardwood demand; four parishes had only low hardwood demand levels (Table 28, Figure 30).

Based on the demand delineation shown in Table 28, the competition for the hardwood resource was relatively low, and the major criterion used to locate the area of high hardwood procurement potential should probably be based on the growing stock levels within the study region.

An analysis was made of the overlay of ownership, and high and low demand levels of hardwood pulpwood (Table 29). This table reveals that 76.3 percent of the area of low demand occurred in parishes with more than 60 percent NIPF

Table 28. Area calculation of northwest Louisiana pulpmill hardwood demand levels by parish.

	Demand Level (hectares)			
Parish	Low	Medium	High	Total
Bienville	172,656	34,286	3,138	210,080
Bossier	213,218			213,218
Caddo	234,188	842		235,030
Caldwell	104,007	19,924		123,931
Claiborne	73,853	40,792	77,833	192,478
De Soto	213,984	9,719		223,703
Jackson	124,900	15,572		140,472
Lincoln	112,349			112,349
Ouachita	157,580			157,580
Red River	71,710	33,675		105,385
Union	230,132			230,132
Webster	63,369	87,705	7,500	158,574
Winn	24,490	124,365	88,777	237,632
Total	1,796,514	366,802	177,248	2,340,564

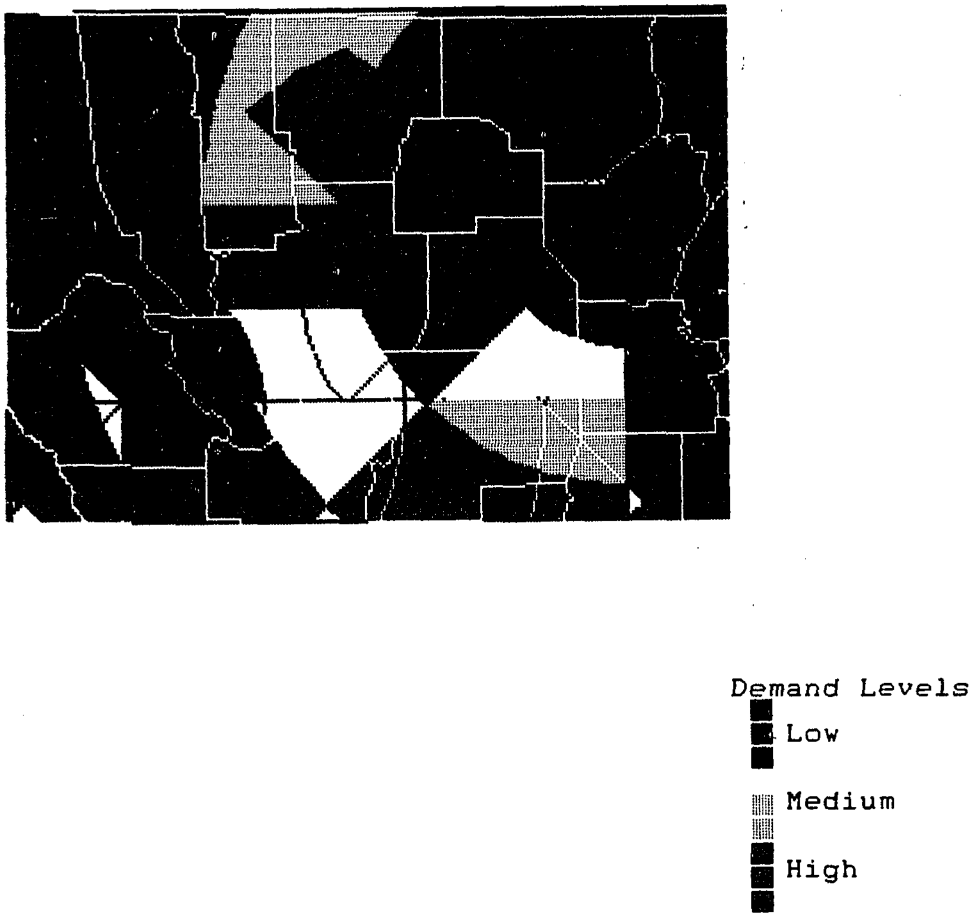


Figure 30. Overlay of hardwood procurement segments of pulpmills in northwest Louisiana.

Table 29. Hardwood pulpwood demand levels at northwest Louisiana pulpmills, by ownership classification.

Ownership Percent	Demand Level (hectares) High	Low
NIPF < 30	88,777	24,490
30 - 39		
40 - 49	3,138	401,564
50 - 59		
60 - 69	7,500	664,375
70 - 79		71,710
80 - 90	77,833	287,914
> 90		346,461
Total	177,248	1,796,514
For Ind < 30	85,333	1,140,328
30 - 39		230,132
40 - 49		104,007
50 - 59	88,777	149,391
60 - 69	3,138	172,656
70 - 79		
80 - 89		
> 90		
Total	177,248	1,796,514

ownership. Thus, the area of low hardwood demand encompasses a large area of potentially high hardwood availability.

As was indicated in Table 3, the average removal of hardwood pulpwood in the study region was only 29.3 percent of the total pulpwood removal; also, hardwood growing stock was 38.2 percent of the total growing stock. As was shown in Table 12 the ratio of growth to removals of hardwood growing stock was 1.40:1. Thus, one can infer an under-utilization of this resource over the entire study region, and the large area of low hardwood pulpwood demand in Figure 30 reflected this situation.

The area of high demand for hardwood pulpwood is almost completely within the lowest level of removals of hardwood pulpwood, while large areas of low demand occur in the areas of highest pulpwood removals per hectare (Table 30). This may imply possible inconsistencies in the assignment of volumes to the hardwood demand segments.

The parishes of Bossier, Caldwell, Ouachita, and Red River had the highest levels of hardwood growing stock in the region, and also had 68 to 100 percent coverage of low demand levels. These parishes are likely candidate parishes for expansion of hardwood pulpwood procurement effort.

Table 30. Area of low hardwood demand at northwest Louisiana pulpmills and hardwood pulpwood removals.

Removals (m^3 per ha.)		Demand Level (hectares) High	Low
< 1.00		174,110	467,611
1.00	1.10	3,138	385,875
1.11	1.20		
1.21	1.30		318,067
1.31	1.40		269,929
1.41	1.50		
1.51	1.60		355,032
> 1.60			
Total		177,248	1,796,514

Woodyard Total Demand

Circular procurement zones. The overlay of total pulpwood demand by the pulpwood concentration yards in the study region was produced from the segmented procurement zones of the 24 respondents and 10 nonrespondents that were assigned median pulpwood volumes (Figure 31). The overlay was composed of 84 distinct demand levels that were divided into three demand classes: low demand was less than 38 levels of demand, medium demand ranged from 39 to 69, and high demand was from 70 to 99. The demand level classification used in the woodyard demand analysis was differentiated at different points as compared to the pulpmill demand analysis, and was not directly comparable to the pulpmill demand analysis. The scales used for demand levels are interval estimates, and should only be used within the respective respondent classification. The scale appears to portray greater than 84 demand levels, but there are empty cells at the extreme ends of the distribution. Once again, the color pattern is of increasing intensity for higher levels of demand within each demand class. The clarity of the woodyard overlay is not as distinct as the pulpmill total demand overlay shown in Figure 18. Obviously, the greater number of respondents in many locations adds to the lack of distinctness and greater noise in the overlay.

Demand Levels
Low
Medium
High

Figure 31. Overlay of total pulpwood demand of all woodyards within the northwest region of Louisiana.

The digitized areas of low and high demand classes are shown in Figures 32 and 33, with the area of each demand class by parish exhibited in Table 31. A comparison of the area of low demand by the woodyards to that of the pulpmills (Table 14), reveals that the areas of demand by the two respondent classes are not equivalent. Although an area of low pulpwood demand appears in the northwest region of both figures, there are conflicts of demand classification in De Soto and Winn parishes. The southern portions of these parishes are shown to be areas of low demand by the woodyards, but are within the area of highest demand by pulpmills. This confusion may result from the pulpmills obtaining high volumes of pulpwood from the woodyards within these parishes, while the woodyards located in these parishes are procuring much of their pulpwood volumes from outside of their parish of operation.

The comparison of high total woodyard demand to areas of high pulpmill demand produces less inconsistencies than the low demand comparison (Figure 33). The area of high total demand by the woodyards that is located in the eastern parishes of the study region generally follows that of the pulpmill demand area, but does not clearly concur with the other parishes containing high pulpmill demand. Of interest in this comparison is the lack of any areas of high woodyard demand in Winn and Claiborne parishes. As exhibited in Table 31, Winn parish contained 77.2 percent of its parish area in the low demand classification; Claiborne has no

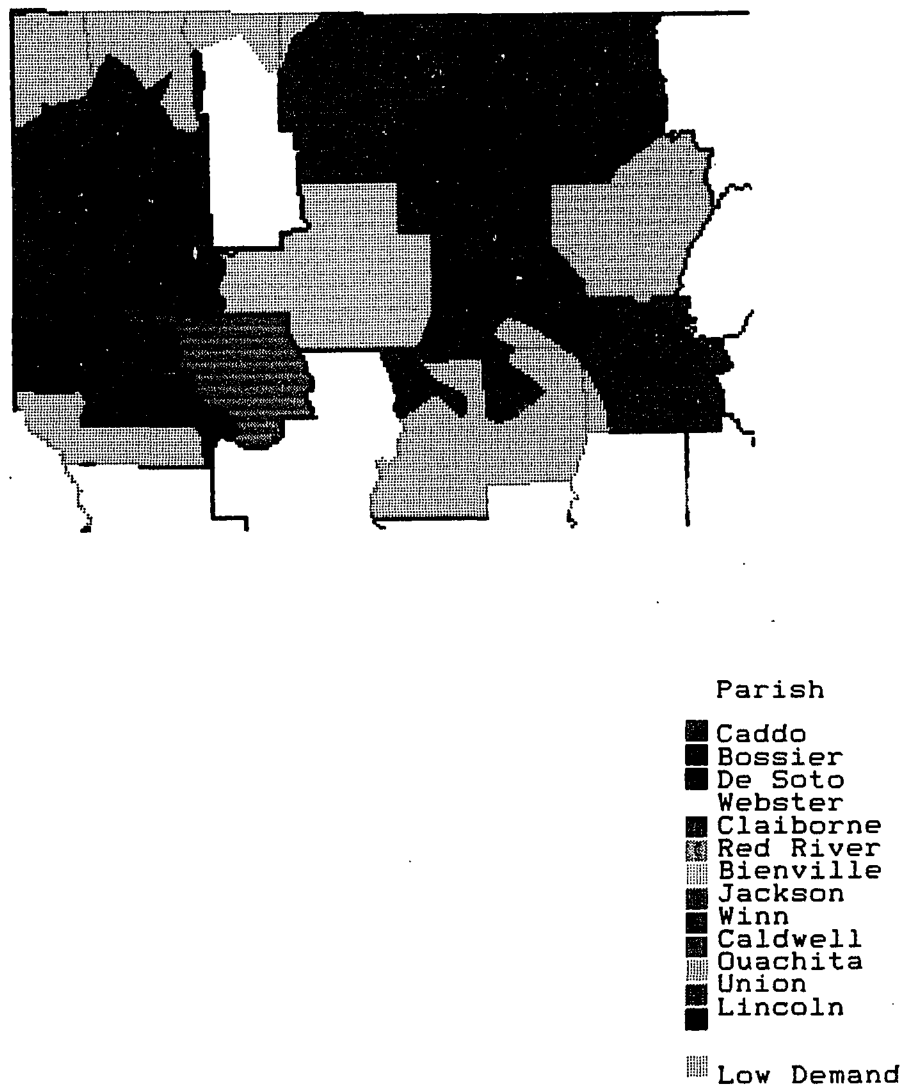


Figure 32. Area of low total pulpwood demand by woodyards within the study region.

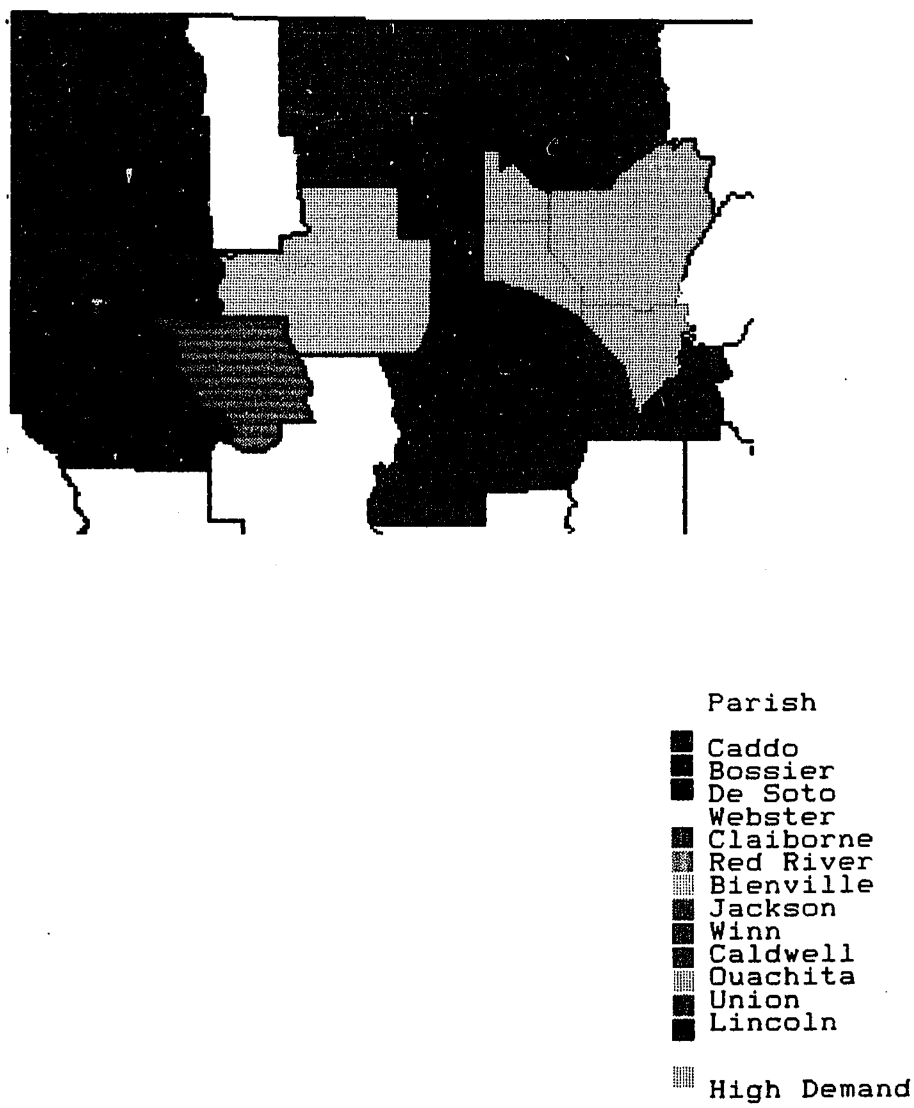


Figure 33. Area of high total pulpwood demand by woodyards within the study region.

Table 31. Area of total pulpwood demand at northwest Louisiana woodyards, by parish.

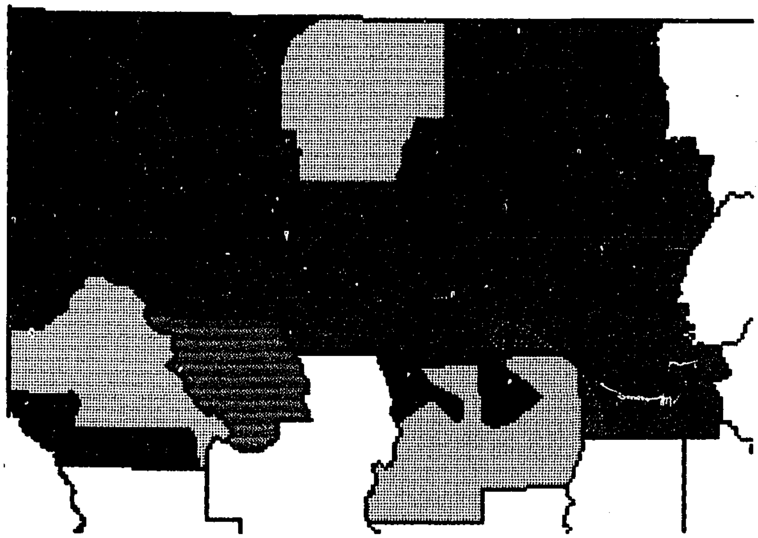
	Demand Level (hectares)			
Parish	Low	Medium	High	Total
Bienville		204,953	5,127	210,080
Bossier	60,691	152,527		213,218
Caddo	58,317	176,613		235,030
Caldwell	6,505	67,604	49,822	123,931
Claiborne	5,434	187,044		192,478
De Soto	64,210	159,493		223,703
Jackson	9,490	86,670	44,312	140,472
Lincoln		85,869	26,480	112,349
Ouachita		79,135	78,445	157,580
Red River		105,385		105,385
Union		230,132		230,132
Webster	26,097	132,477		158,574
Winn	183,371	54,261		237,632
Total	414,115	1,722,263	204,1860	2,340,564

areas of high demand, and the northwest corner of the parish had approximately 3 percent of its area in the low demand classification. This information will be beneficial in the relocation assessment of selected wood concentration yards.

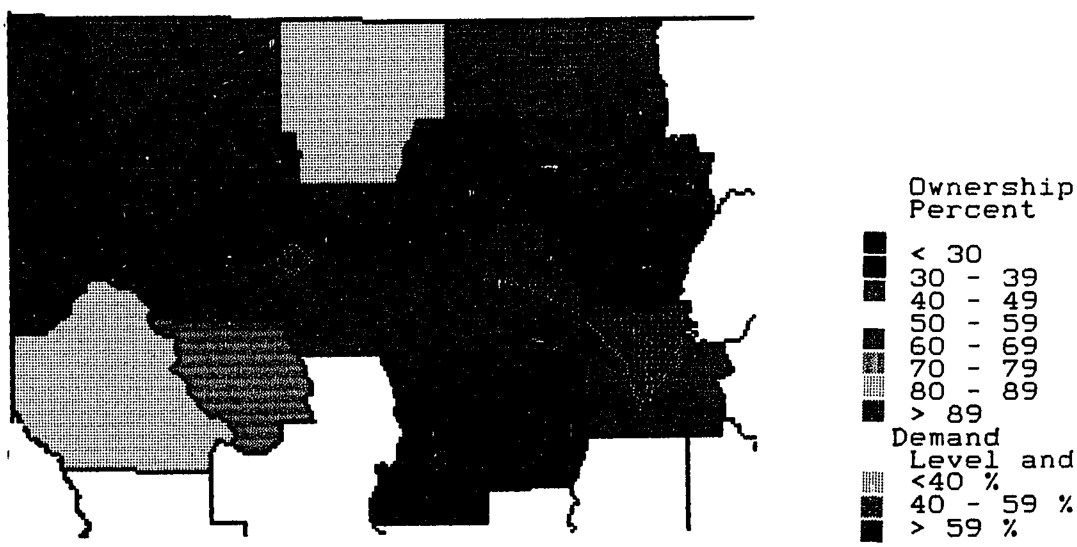
The overlay of ownership with high and low levels of woodyard demand is shown in Figures 34 and 35. Within ownership classifications there do not appear to be any significant trends of interest (Table 32).

The intersection of woodyard total pulpwood demand and pulpwood removals is shown in Figure 36. The area of low demand and lowest removals occurred in the northern portion of Caddo, Bossier, and Webster parishes, while southern De Soto and Winn parishes were of low demand but higher levels of removals. The demand level by removal class (Table 33), reveals that the level of high demand is distributed in the middle of the range of pulpwood removals, with the highest level of demand and removals occurring in Jackson parish.

The overlay produced for analysis of total pulpwood demand and the intersection of total growing stock is shown in Figure 37. The area of low demand and highest growing stock level was in northern Bossier parish, and the parishes of low demand and lowest growing stock levels were in Caddo, Winn, and Caldwell parishes. The area of high demand and the lowest two growing stock levels (Table 34) consisted of areas in Caldwell and Ouachita parishes; together these parishes comprised 62.8 percent of the high demand area.

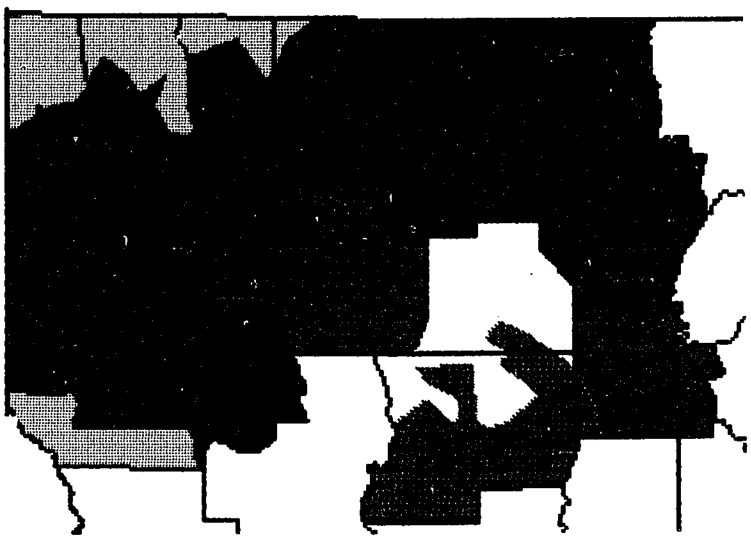


a. Low woodyard demand.

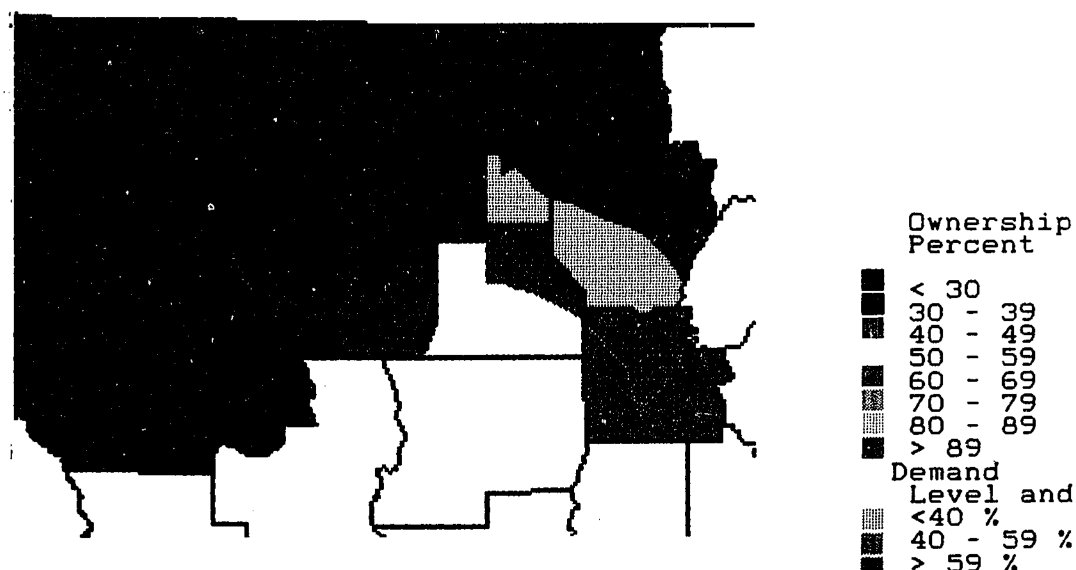


b. High woodyard demand

Figure 34. Woodyard demand classes overlaid on NIPF ownership percentage.



a. Low woodyard demand.

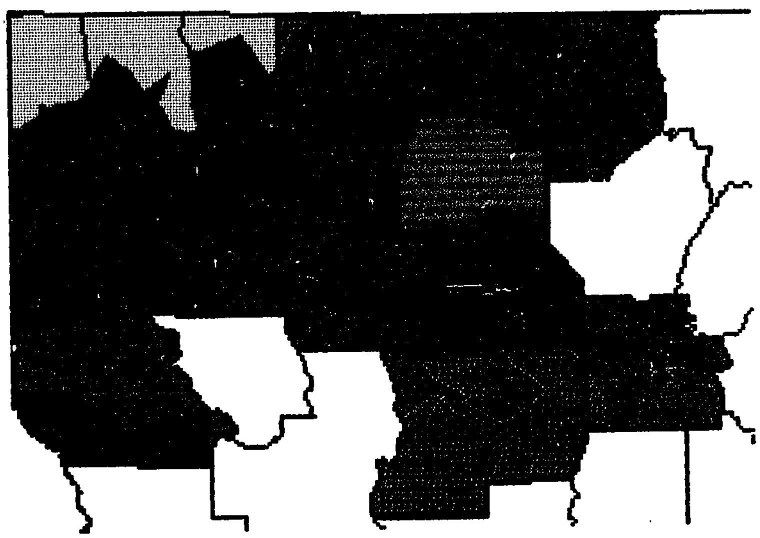


b. High woodyard demand.

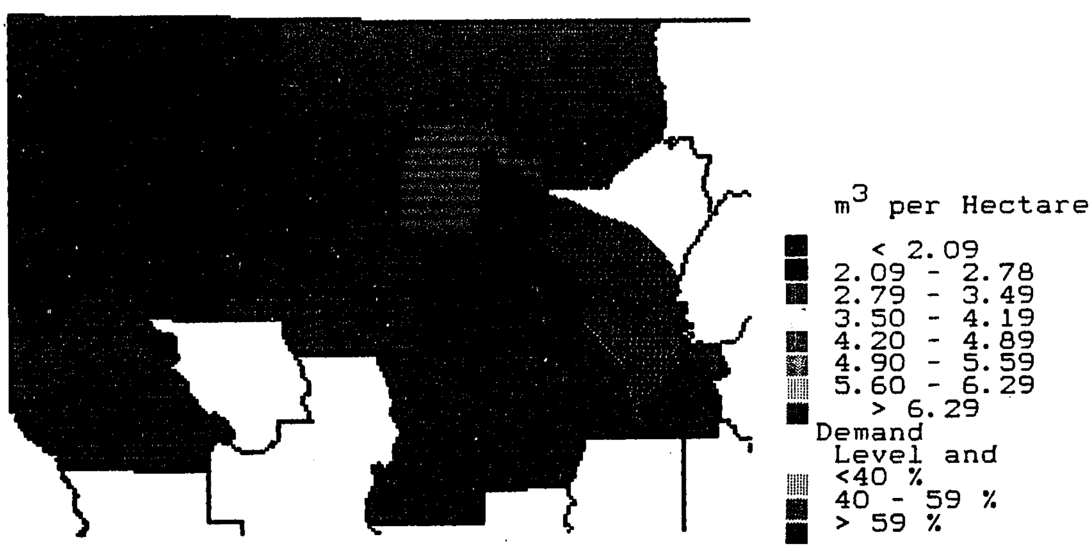
Figure 35. Demand classes of woodyards overlaid on forest industry ownership percentage.

Table 32. Total pulpwood demand levels at northwest Louisiana woodyards by ownership classification.

Ownership	Percent	Demand Level (hectares) Low	High
NIPF	< 30		
	30 - 39		
	40 - 49	15,995	99,262
	50 - 59		
	60 - 69	86,711	78,445
	70 - 79		
	80 - 90	69,721	
	> 90	58,317	26,480
Total		414,115	204,186
For Ind	< 30	214,749	104,926
	30 - 39		
	40 - 49	6,505	49,822
	50 - 59	197,861	44,312
	60 - 69		5,127
	70 - 79		
	80 - 89		
	> 90		
Total		414,115	204,186



a. Low woodyard demand.



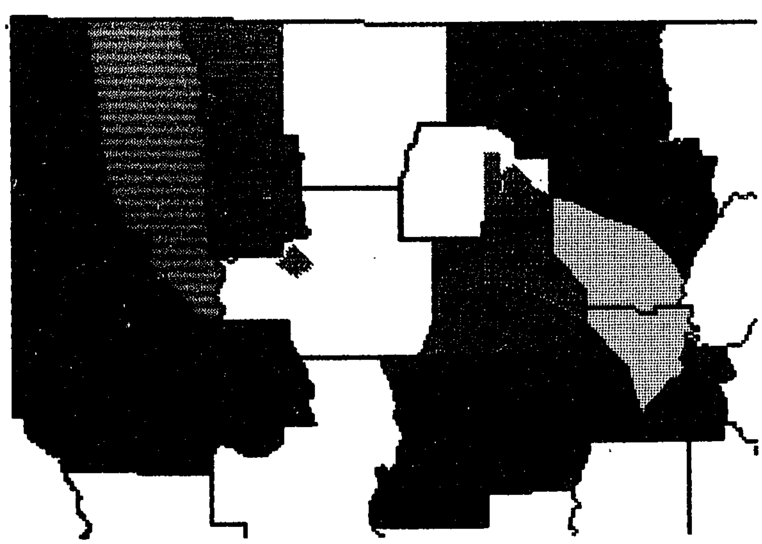
b. High woodyard demand.

Figure 36. Woodyard demand levels overlaid on reported total pulpwood removals.

Table 33. Area of total pulpwood demand at northwest Louisiana woodyards and total pulpwood removals.

Removals (m^3 per ha.)		Demand Level (hectares) Low	High
< 2.09		58,317	
2.09	2.72	86,710	
2.79	3.42	195,310	49,822
3.49	4.12		78,445
4.19	4.82	64,287	5,127
4.89	5.52		26,480
5.59	6.22		
> 6.28		9,490	
Total		414,115	204,186

a. Low woodyard demand.



b. High woodyard demand.

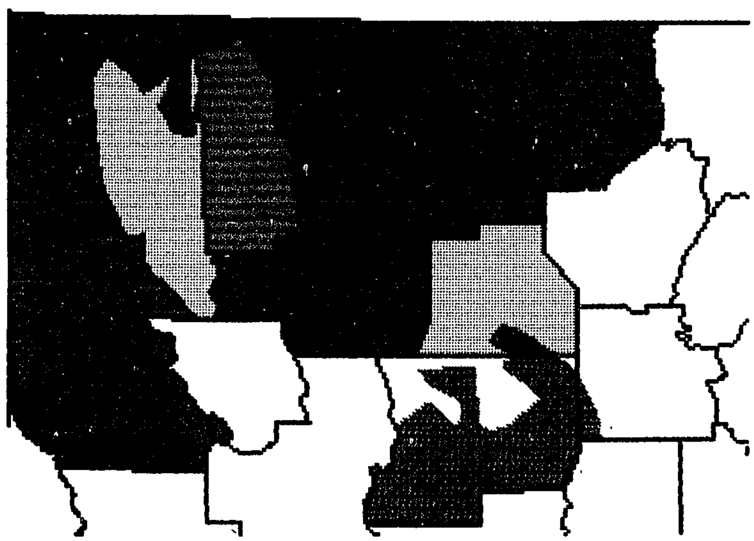
Figure 37. Woodyard demand levels overlaid on average total growing stock.

Table 34. Area of total pulpwood demand at northwest Louisiana woodyards and total growing stock levels.

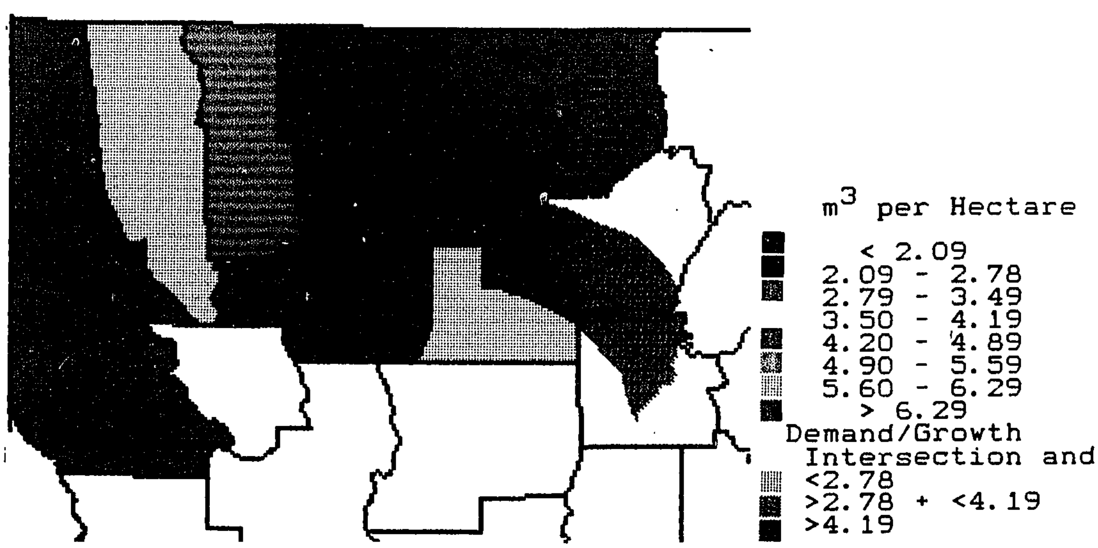
Growing Stock (m^3 per ha.)		Demand Level (hectares) Low	High
< 20.95		248,193	49,822
20.95	27.86	64,210	78,445
27.93	34.85	35,587	44,312
34.92	41.83	5,434	31,608
41.90	48.81		
48.88	55.80	60,691	
55.87	62.78		
> 62.85			
Total		414,115	204,186

The overlay of demand levels and total average annual growth produced the highest growth and low level demand in northern Bossier parish (Figure 38). The areas of high demand and the lowest occurring level of growth were in Red River, Ouachita, and Caldwell parishes (Table 35).

The rating table of total pulpwood procurement factors for the woodyards is exhibited in Table 36. Winn parish has the highest percentage of low pulpwood demand area, but had a very low growing stock level and the lowest percentage of NIPF ownership. De Soto parish with the second highest percentage of low demand area has removals of approximately 25 percent greater than growth. The northern portions of Bossier, Caddo, and Webster parishes appear to offer the best opportunity for the expansion of procurement effort. Bossier parish has the third lowest level of removals to growth, and the highest level of growing stock. Caddo parish ranks very low in the level of growing stock, but it has the lowest percentage of removals to growth, and the second highest NIPF ownership percentage in the study region. Although Webster parish was fifth in area of low demand, it had the fourth lowest level of removals to growth, a high NIPF ownership percentage, and was in the upper one-third of growing stock per hectare. A factor that should be considered in the expansion of procurement effort in these parishes is the presence of the Shreveport/Bossier City urban area, located in the southern portion of Caddo and Bossier parishes.



a. Low woodyard demand



b. High woodyard demand

Figure 38. Average net annual growth of growing stock and total woodyard demand intersection.

Table 35. Area of demand of total pulpwood at northwest Louisiana woodyards and average annual growth of total growing stock.

Growth (m^3 per ha.)		Demand Level (hectares) Low	High
< 1.40			
1.40	2.03		
2.09	2.72		
2.79	3.42	189,876	128,267
3.49	4.12	122,527	
4.19	4.82	26,097	
4.89	5.52	70,181	44,312
> 5.59		5,434	31,607
Total		414,115	204,186

Table 36. Rating of key wood procurement factors for northwest Louisiana woodyard total pulpwood demand.

Parish	Percent of Low Demand Area	Percent NIPF Ownership	Removals/ Growth (m^3/ha)	[1]Rank of Grow Stk
Bienville	0.0	40.00	80.95	11
Bossier	28.5	63.13	67.08	13
Caddo	24.8	94.74	46.02	2
Caldwell	5.2	39.55	105.96	4
Claiborne	2.8	85.22	62.76	10
De Soto	28.7	81.25	125.36	7
Jackson	6.8	42.86	153.84	8
Lincoln	0.0	94.86	94.08	12
Ouachita	0.0	69.46	117.02	5
Red River	0.0	73.08	135.53	1
Union	0.0	61.27	121.01	6
Webster	16.5	67.26	71.51	9
Winn	77.2	26.91	143.57	3

[1] Higher values indicate higher levels of growing stock per hectare.

Highway Distance Isoline Zones. The woodyards in the study region were dependent on the use of trucks for the transport of pulpwood. Therefore, the use of highway distance isolines to delineate procurement zones for the woodyards was assumed to be a sound approach to the problem of characterizing areas of wood demand. Isolines were constructed for two contour intervals of 40.2 kilometers (25 miles) each. Two intervals were used rather than four, as 74 percent of the pulpwood procured by the woodyards was produced within these two zones, and for the demonstration of woodyard relocation on pulpwood demand effects, it was presumed to be adequate.

The overlay of the total pulpwood demand based on highway distance isolines is shown in Figure 39. Once again, three demand levels were differentiated, based on a histogram analysis. The area of lowest total demand was predominately in the northwest and southern portion of the study region (Table 37). In comparing the isoline demand overlay to the previous circular zone delineation (Figure 31), the areas of low and medium demand are much smaller and the area of high demand is considerably larger. This is because of both the reduction in the number of procurement zones used and the smaller area encompassed by the procurement segments delineated by the highway distance isoline.

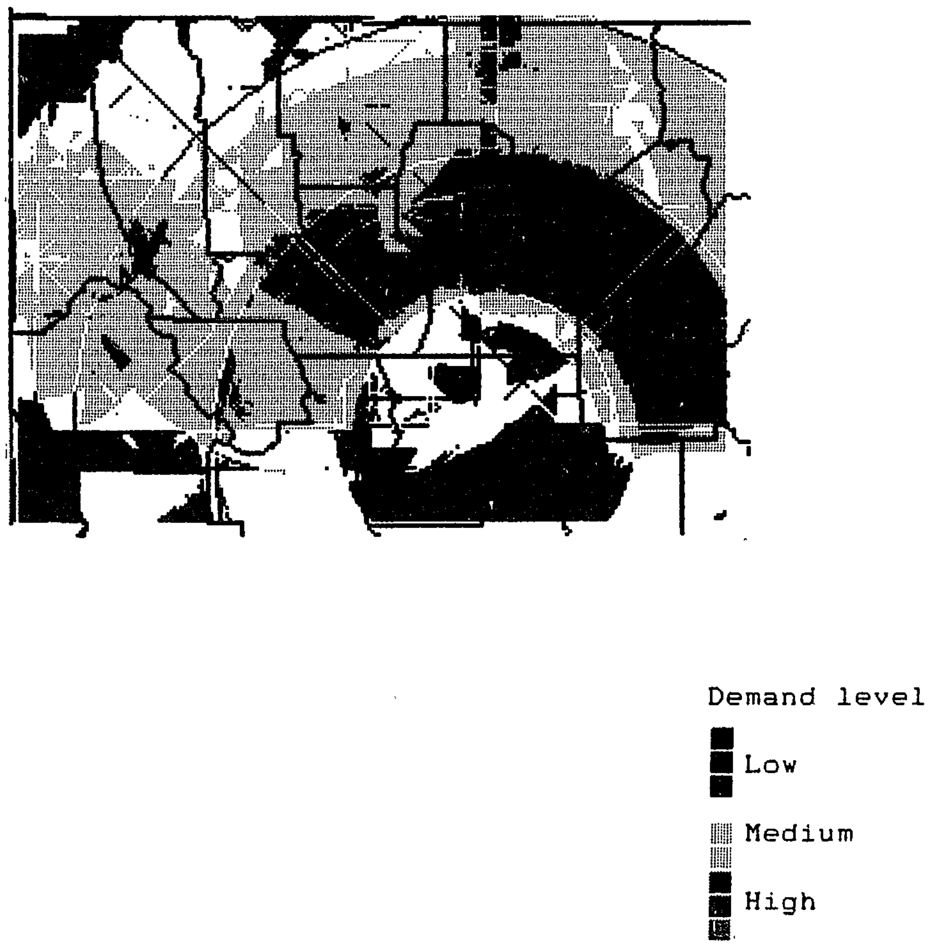


Figure 39. Overlay of total pulpwood demand for woodyards based on a highway distance isoline.

Table 37. Area of total pulpwood demand at northwest Louisiana woodyards using highway distance isolines, by parish.

Parish	Demand Level (hectares) Low	Medium	High	Total
Bienville		83,037	127,043	210,080
Bossier	14,618	191,253	7,347	213,218
Caddo	55,868	171,356	7,806	235,030
Caldwell	3,903	25,587	94,441	123,931
Claiborne	17,373	175,105		192,478
De Soto	54,644	168,294	765	223,703
Jackson	21,506	52,689	66,277	140,472
Lincoln		36,123	76,226	112,349
Ouachita		23,700	133,880	157,580
Red River		94,135	11,250	105,385
Union		200,744	29,388	230,132
Webster	4,975	153,370	229	158,574
Winn	142,656	94,976		237,632
Total	315,543	1,470,369	554,652	2,340,564

The evaluation of the key wood procurement factors for woodyard total demand based on the highway distance isolines (Table 38) is identical to the rating table previously exhibited for the circular procurement zones, except for the column of low demand area percentage. But, these tables cannot be directly compared. They can only be compared by parish relative to the other parish statistics within each of the tables. Caddo parish, with the lowest removals to growth percentage, had the third highest area of low demand, highest NIPF ownership, but was the second lowest ranked parish in growing stock per hectare. De Soto parish had the second highest percentage area of low demand, but had removals 25 percent greater than growth (Table 38). Bossier parish had the third lowest removal to growth percentage, in conjunction with the highest ranking of total growing stock per hectare, but had only 6.9 percent of its area in the low demand classification. Webster parish had the fourth lowest removals to growth, with a high level of NIPF ownership, but a small percentage of low demand area. Winn parish had the highest percentage of low demand area, but was ranked low in growing stock per hectare, had a low NIPF percentage, and removals were 43 percent greater than growth. Again, the northwest portion of the study region appears to be an area warranting an expansion of the wood procurement effort. Jackson parish, which had 15.3 percent of its area in low demand, and Red River parish which had the lowest level of growing stock per hectare, had total removals exceeding

Table 38. Rating of key wood procurement factors for northwest Louisiana woodyard total pulpwood demand based on highway distance isoline procurement zones.

Parish	Percent of Low Demand Areas	Percent NIPF Ownership	Removals/ Growth (m^3/Ha)	[1]Rank of Grow Stk
Bienville	0.0	40.00	91.61	11
Bossier	6.9	63.13	39.57	13
Caddo	23.8	94.74	41.57	2
Caldwell	3.1	39.55	85.02	4
Claiborne	9.0	65.22	51.25	10
De Soto	24.4	81.25	98.96	7
Jackson	15.3	42.86	152.04	8
Lincoln	0.0	94.86	88.06	12
Ouachita	0.0	69.46	91.69	5
Red River	0.0	73.08	158.98	1
Union	0.0	61.27	83.49	6
Webster	3.1	67.26	48.19	9
Winn	60.0	26.91	87.43	3

[1] Higher values indicate higher levels of growing stock per hectare.

annual growth by 35 percent or more, and should be considered as an area warranting a reduction of procurement effort.

Simulation Analysis of Woodyard Relocation. The effects of moving several selected woodyards within the study region was evaluated through an iterative procedure. This was an attempt to smooth demand levels over the study region, and redistribute regional pulpwood market purchase levels. Although a specific point of relocation was selected, it should not be considered as optimal or inflexible, but only as one of many possible alternatives. A heuristic evaluation of key wood procurement factors and location of urban areas was used to determine which of the areas within the study region were best suited for the expansion of total wood procurement effort. The key wood procurement factors evaluated were area percentage of low demand, percentage of removals to growth, parish ranking of total growing stock per hectare, and percentage of NIPF ownership. Four low demand parishes ranked in order of expansion potential were Bossier, Caddo, Claiborne, and Webster, which together constituted the northwest portion of the study region. The parishes of highest total demand were Bienville, Ouachita, and Caldwell. These parishes were selected as potential parishes for total pulpwood demand reduction by relocating woodyards and their respective total pulpwood demand to areas of lower total pulpwood demand within the study region.

As the demand overlay of highway isoline demand (Figure 39) was based on the actual highway network surrounding each woodyard, a relocation model of highway distance isolines, in meters, was developed from a simple regression analysis. The regression model was:

$$PR = 3035.26316 + 0.77126744(SL) + e_i$$

where: PR = effective isoline procurement radius,

SL = straight-line distance from woodyard location to the mean woodyard isoline distance.

This linear model had an R^2 of 88.03. The model had produced circular zones of radii 34,082 and 65,084 meters (19.9 and 41.8 miles) for the two zones closest to the woodyard center. These zones were produced at the newly selected locations to model the effect of a highway distance isoline. The eight corridor procurement system was combined with these procurement zones to produce highway distance isoline procurement segments for each new woodyard location.

Three woodyards were selected for relocation. Their selection was based on their demand levels and present location in high demand areas, and thus the impact that their relocation would have on reducing the area of high demand in the study region. The new locations were selected after an evaluation of the previously described key wood procurement factors, highway network, urban areas, and location of non-traversable water bodies that would impede truck movement. Care was taken to place the woodyard at a new location such that an approximately equal area occurred outside of the study region at the new location as occurred at the previous location. This evaluation was based on the blocked study region as shown in Figure 39, with demand areas shown in Table 39.

The first woodyard to be relocated was that of respondent 38, which had the third highest total pulpwood volume procured of all woodyards, and also had a significant portion of its pulpwood demand within the area of high demand. This woodyard was relocated from Winn parish to northwest Bossier parish, in the vicinity of the Rocky Mount community; thus, the new procurement zone was mainly within the area of Bossier, Caddo, and Webster parishes. For this new location, Figure 40 shows the primary-arterial highway network within the study region, minor-arterial highway system in the potential relocation area, the Shreveport urban area, and the location of major waterbodies in the region.

The effects of this relocation on demand levels are displayed in Figure 41, with the results of the change in demand level areas shown in Table 40. This relocation produced only a slight decrease in the area of high demand, and a increase in the area of low demand of 7.6 percent.

The second woodyard selected for relocation was that of woodyard respondent 36. This respondent was also located in Winn parish. The isoline procurement overlay of woodyard 36 was subtracted from the demand classification resultant from the first woodyard relocation shown in Figure 41, and

Table 39. Area of demand classification for northwest Louisiana woodyard total pulpwood demand portrayed by highway distance isolines in blocked study region.

Demand Class	Demand Level	Area (hectares)	Percent
Low	1 - 32	480,005	15.0
Medium	33 - 55	2,072,851	64.7
High	56 - 84	650,596	20.3
Total		3,203,452	100.0

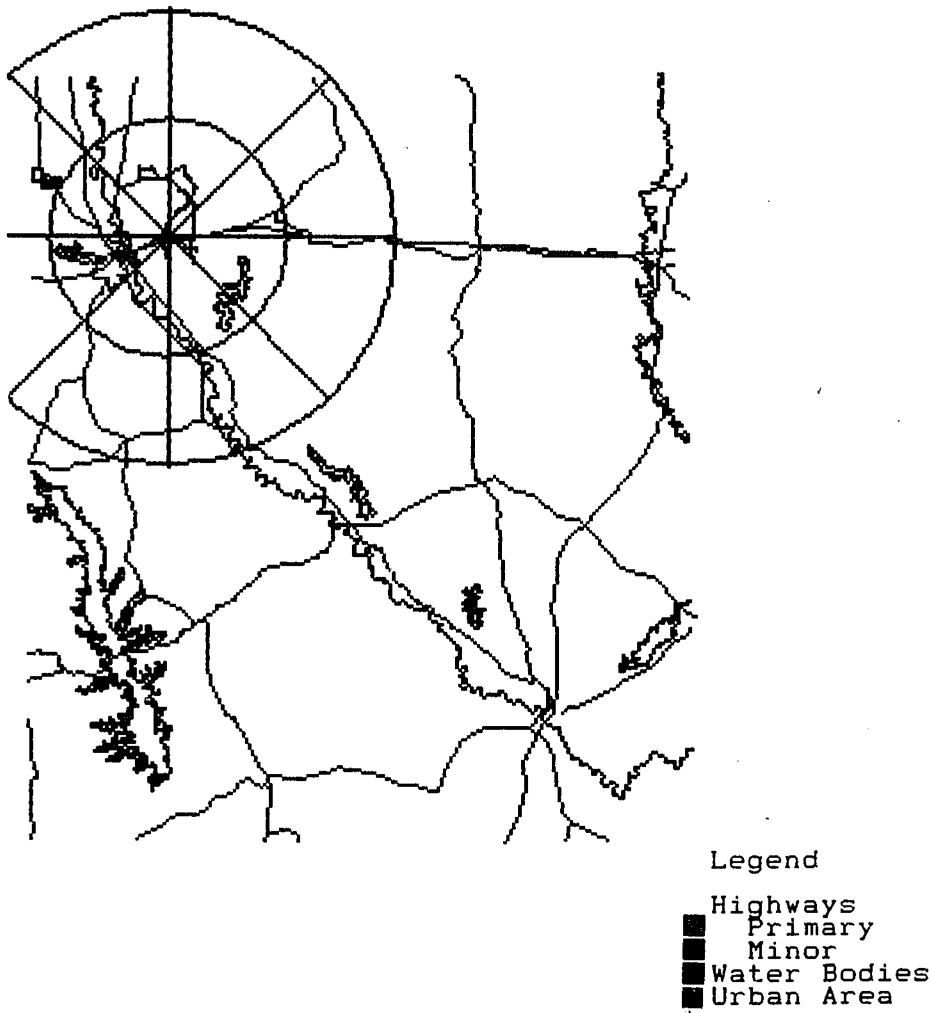


Figure 40. Proposed relocation area of first woodyard, respondent 38.

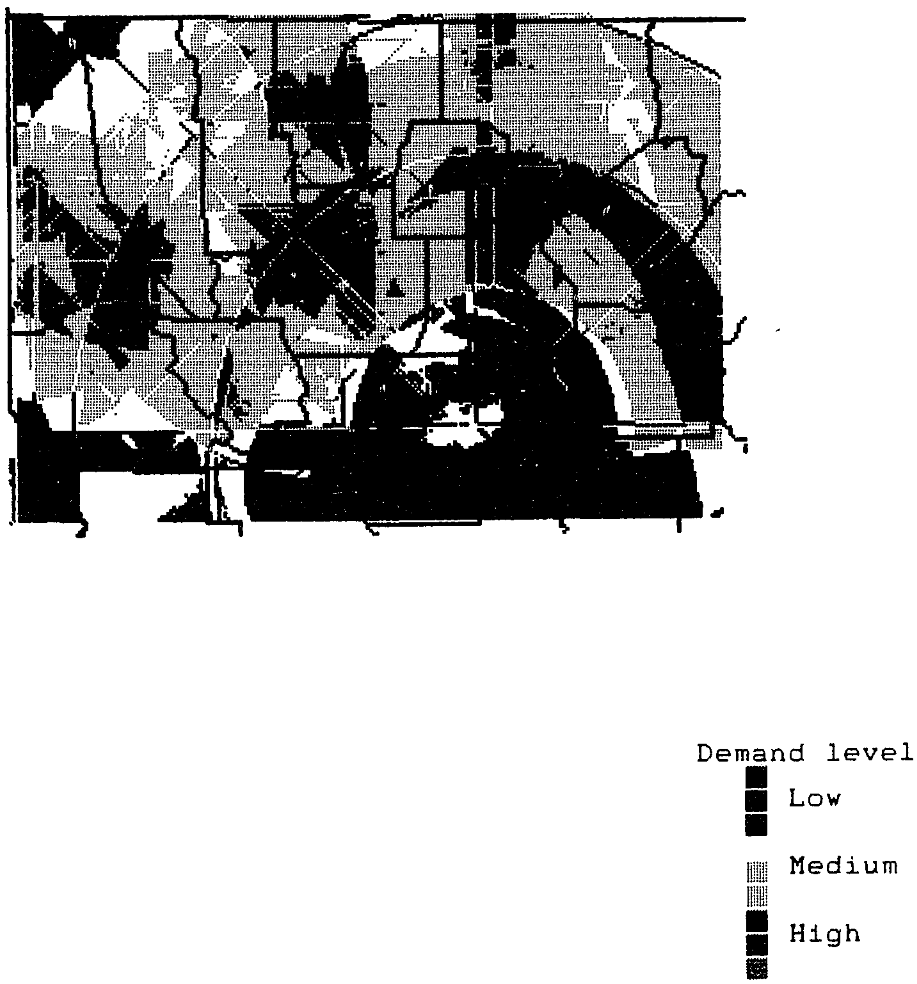


Figure 41. Overlay of total pulpwood demand for woodyards based on a highway distance isoline, after relocation of woodyard 38.

Table 40. Area of demand classification for northwest Louisiana woodyard total pulpwood demand portrayed by highway isolines with woodyard respondent 38 moved to northwest Bossier parish.

Demand Class	Demand Level	Area (hectares)	Percent
Low	1 - 32	723,373	22.6
Medium	33 - 55	1,832,145	57.2
High	56 - 86	647,934	20.2
Total		3,203,452	100.0

woodyard 36 was then relocated near the west Claiborne parish boundary. The simulated location was in the vicinity of Langston, to take advantage of the area of low demand in Claiborne and Webster parishes. The procurement classification resultant from this relocation is exhibited in Figure 42, and the area by demand class is shown in Table 41. Although the number of demand levels increased from 84 to 86, the area of high demand decreased by an additional 0.9 percent and the area of low demand increased by 0.7 percent.

The final woodyard to be relocated in the analysis was woodyard respondent 21, located in Lincoln parish. The new location selected for this woodyard was near the Bossier/Webster parish boundary, in the vicinity of Cotton Valley. The effect of the highway isoline demand for this respondent was subtracted from the most recent relocation classification (Figure 42), and the woodyard demand of respondent 21 was added to the classification at the new location (Figure 43). The area of high demand increased by 1.1 percent, and low demand area increased by 0.8 percent (Table 42). Ideally, the area of high demand would have continued the previous reduction trend. This trend could be further explored by additional movement of the woodyard location for evaluation.

As compared to the original woodyard location isoline analysis exhibited in Table 37, the relocation of respondent woodyards 38 and 36 produced a reduction in the area of high

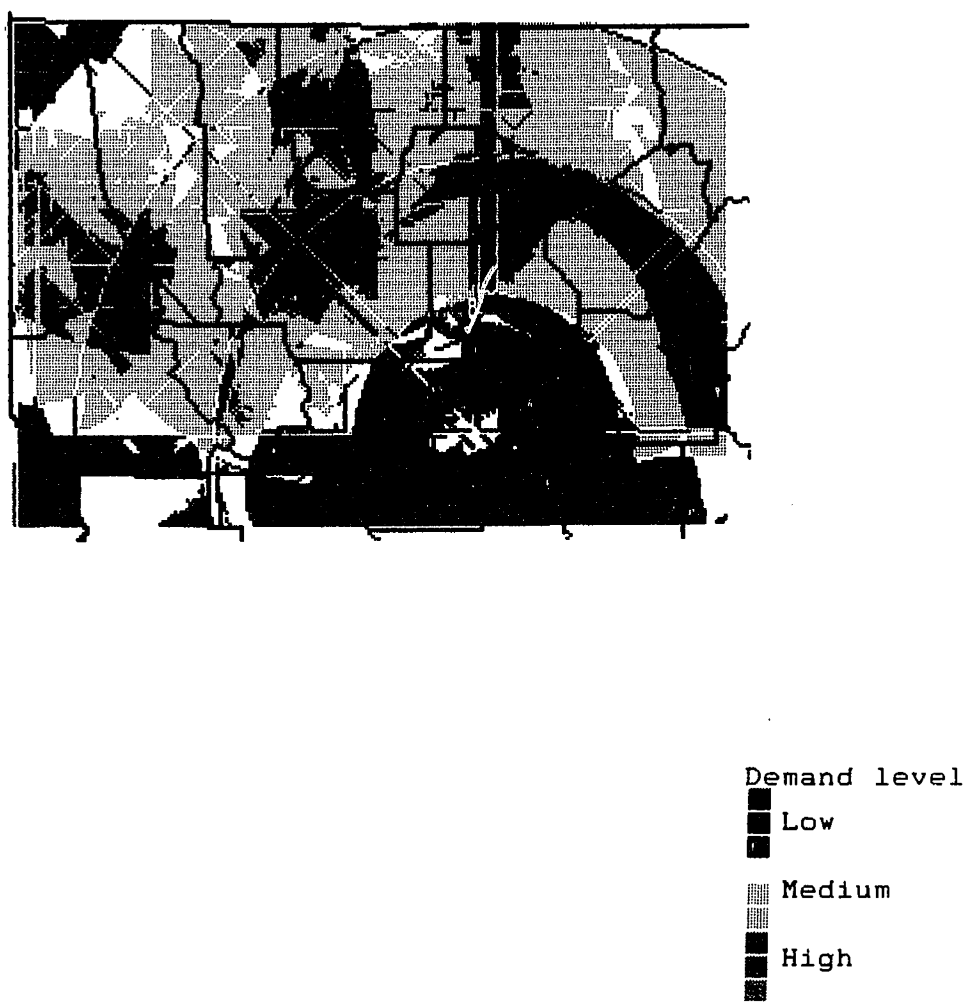


Figure 42. Overlay of total pulpwood demand for woodyards based on a highway distance isoline, after relocation of woodyards 38 and 36.

Table 41. Area of woodyard total pulpwood demand classification portrayed by highway isolines with respondent yards 38 and 36 moved to the northwest area of the northwest Louisiana region.

Demand Class	Demand Level	Area (hectares)	Percent
Low	1 - 32	747,772	23.3
Medium	33 - 56	1,837,697	57.4
High	57 - 87	617,983	19.3
Total		3,203,452	100.00

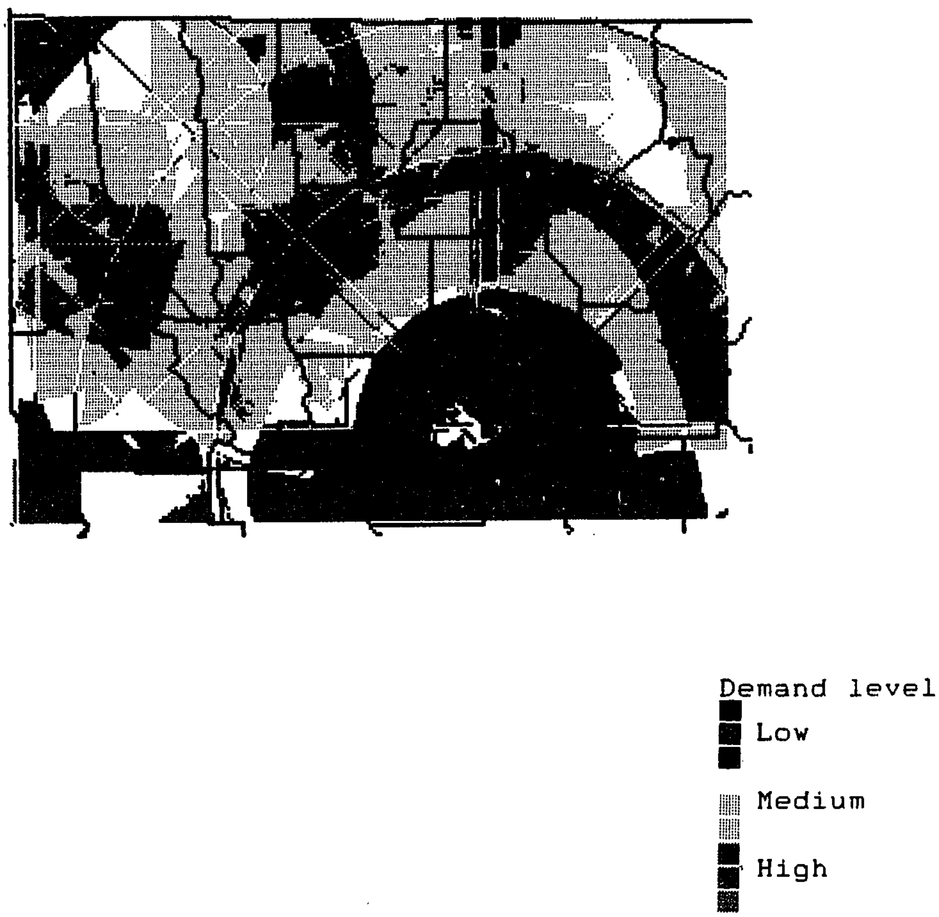


Figure 43. Overlay of total pulpwood demand for woodyards based on a highway distance isoline, after relocation of woodyards 38, 36, and 21.

Table 42. Area of woodyard total pulpwood demand classification portrayed by highway isolines with woodyard respondents 21, 38, and 36 moved to the northwest area of the northwest Louisiana region.

Demand Class	Demand Level	Area (hectares)	Percent
Low	1 - 32	773,787	24.1
Medium	33 - 56	1,775,688	55.4
High	57 - 92	653,977	20.4
Total		3,203,452	100.00

demand of 6.9 percent, in conjunction with a low demand area increase of 69.5 percent (Table 43).

The comparison by parish of the effect of the woodyard relocation is exhibited in Table 44. One can observe six parishes where areas of high demand were reduced. Six parishes had an increase in the area of high demand, and Winn parish remained with no areas of high demand. In addition, the areas of low demand were increased in five parishes. Jackson and Red River parishes, that had removals in excess of growth, had their low demand areas increased and high demand area decreased.

The relocation of these woodyards, especially woodyards 38 and 36, could possibly increase the value of pulpwood stumpage in the northwest portion of the study region, and reduce wood procurement costs for those woodyards remaining in what was originally the high demand area in the central portion of the study region. In addition, the potential problem of overcutting in Jackson and Red River parishes may be reduced while increasing removals from the four northwestern parishes that had approximately 50 percent or less of removals to growth.

Table 43. Area delineated by highway distance isolines of total pulpwood demand at northwest Louisiana woodyards by parish, after relocation of woodyard respondents 38 and 36.

	Demand Level (hectares)			
Parish	Low	Medium	High	Total
Bienville	13,316	97,732	99,032	210,080
Bossier	9,184	190,411	13,623	213,218
Caddo	41,710	123,752	69,568	235,030
Caldwell	30,766	53,751	39,414	123,931
Claiborne		118,012	74,466	192,478
De Soto	52,271	136,381	35,051	223,703
Jackson	66,583	45,572	28,317	140,472
Lincoln		41,251	71,098	112,349
Ouachita		85,716	71,864	157,580
Red River	2,832	91,609	10,944	105,385
Union		184,519	45,613	230,132
Webster		138,523	20,051	158,574
Winn	237,632			237,632
Total	454,294	1,307,229	519,041	2,340,564

Table 44. Comparison of areas of demand by level and parish of highway distance isolines for northwest Louisiana woodyards in present location, with woodyards 38 and 36 moved to proposed locations.

	Woodyard Location Demand Area Percentage			
	Current		Proposed	
Parish	Low	High	Low	High
Bienville	0.00	60.47	6.34	47.14
Bossier	6.86	3.45	4.31	6.39
Caddo	23.77	3.32	17.75	29.60
Caldwell	3.15	76.20	24.83	31.80
Claiborne	9.03	0.00	0.00	38.69
De Soto	24.43	0.34	23.37	15.67
Jackson	15.31	47.18	47.40	20.16
Lincoln	0.00	67.85	0.00	63.28
Ouachita	0.00	84.96	0.00	45.60
Red River	0.00	10.68	2.69	10.38
Union	0.00	12.77	0.00	19.82
Webster	3.14	0.14	0.00	12.64
Winn	60.03	0.00	100.00	0.00

SUMMARY AND CONCLUSIONS

The basic purpose of this project was to characterize the pulpwood procurement environment in northwest Louisiana, and through the use of a GIS, demonstrate an approach to the redistribution of pulpwood market purchase levels in that region.

Characterization of the pulpwood procurement environment was accomplished from survey data acquired from 27 of a total of 40 pulpwood procurement centers in the study area. Several points of interest were determined from this survey. The percentage of pulpwood produced in the study region by wood dealers approximated 50 percent. It would be interesting to monitor this percentage over time, as wood dealers perform in a market middleman role between the landowner, logger, and the pulpmill. Recent trends have shown a reduction in wood volumes produced by pulp company harvesting crews in favor of contract harvesting. As this happens, more reliance is placed on wood dealers to provide required pulpwood volumes, thus creating new business opportunities for additional and existing wood dealers.

The transportation of pulpwood in the study region was found to heavily rely on highway trucks for the movement of pulpwood. The bobtail truck, once the primary means of transporting pulpwood, transported approximately 22 percent of the wood concentration yard purchases.

Tree-length pulpwood and field chips contributed 64 percent to woodyard purchases. This is an indication of the current high level of mechanization of pulpwood harvesting in this region. future monitoring would track the increased mechanization of the regional timber harvesting industry.

An analysis of timber tract evaluation factors revealed that adequate access was the primary concern of wood procurement managers in purchasing a timber tract. Distance from the tract to the initial delivery point, and soil and terrain conditions were also important. The quality of the public highways in the procurement region and tract ownership were the least important factors in timber tract purchase decisions.

Procurement zone perception was evaluated to determine pulpwood transport distances and direction of pulpwood procured relative to each individual procurement center. Fifty percent of the pulpwood concentration yard procurement originated within a 61.6 kilometer (38.3 mile) radius of the woodyard, and 50 percent of the pulpmill pulpwood requirements originated within an 85.8 kilometer (53.3 mile) radius of the pulpmill. The average inbound transport distance for the pulpmills was approximately 16.1 kilometers (10 miles) greater than that reported for all pulpmills in the state in 1971.

An analysis of the effects of pulpwood demand interaction between the pulpwood procurement centers in the study region was accomplished through the use of a micro-computer based GIS. Spatial pulpwood demand data was acquired through the analysis of the questionnaires received from the wood procurement managers in the study region. The pulpwood volumes required by each pulpmill and woodyard location were assigned to a series of procurement segments at varying radii from each wood procurement center. The radii used consisted of both circular procurement zones, and highway distance isolines. Pulpmills and wood concentration yards were analyzed separately.

The pulpmill analysis consisted of the spatial pulpwood demand requirements of the three regional pulpmills by pine, hardwood, and total volume requirements. These requirements were overlaid on other procurement attributes of timberland ownership, pulpwood production, growing stock, and average annual growth by parish. In this manner parish areas of low pulpwood demand intersected with appropriate levels of procurement attributes could be identified for future emphasis of wood procurement efforts. The circular procurement zone analysis revealed that Bossier and Caddo parishes had the largest areas of low pulpwood demand, while Claiborne and Winn parishes were entirely within the region of high total pulpwood demand by the pulpmills. The location of the areas portrayed as low demand were reinforced by the low removals to growth in low demand parishes; but, this was not as clear in the parishes of high demand.

A second analysis of pulpwood demand was done in the same manner, except for the delineation of pulpwood procurement zones as highway distance isolines. The location of demand areas was approximately the same, but there was an increase of the area of low demand for all parishes except for Winn, which remained totally within the high demand level classification. But, the accuracy of one procurement zone delineation as compared to the other could not be assessed, but only surmised.

The total pulpwood demand analysis was conducted using this same approach for the 34 pulpwood concentration yards in the region. The areal extent of the demand levels produced from these overlays was considerably smaller than the demand areas produced in the pulpmill analysis, for both high and low demand areas. The general spatial location was similar to the pulpmill analysis, with the exception of large regions of low demand in De Soto and Winn parishes. The general region that should be emphasized for future wood procurement efforts in this analysis was the northwest portion of the study region, consisting of Caddo, Bossier, Webster, and Claiborne parishes.

A simulation analysis was done to determine the effect on the extent of the area and levels of demand, by simulating the relocation of several woodyards from areas of high pulpwood demand to low demand areas. This relocation was done in an iterative manner, and only several minutes were required to produce a new pulpwood demand model. In the relocation of two woodyards, the area of high demand was reduced 6.9 percent, and the area of low demand was increased 69.5 percent. The potential was shown to produce a more uniform level of demand throughout the study region through these relocations. This could possibly produce benefits for both wood dealers who could concentrate their wood procurement efforts in areas of low demand, and for landowners who own forest land that is currently in the area of low demand.

The microcomputer system used for the GIS analysis has a large potential user base. This is based on the relatively low system cost and good graphics and area analysis capabilities. But, several software deficiencies were encountered during the construction of the GIS. The greatest impediment to the successful use of this system was the elementary database and data structure. The simplicity allowed relative ease of data input, but required a great amount of forethought in assigning attribute values to entities or classes of entities. In addition, the attribute classification system is rigidly structured, and possible interpretation errors in the analysis of the map overlays may result.

The second major shortcoming that was found was the lack of an interactive editing capability of vector data. Thus, errors made in data input were cumbersome to correct. Data entry required a great amount of patience, but this is a dilemma of many GIS's.

The final shortcoming of the software was the inability to determine connectivity and distance to nearest neighbors of given attributes and the inability to construct barriers. Once again, the simplistic data structure contributed to this shortcoming and was found to be a hindrance to this study. These shortcomings resulted in a greater amount of manual interpretation being required in the data analysis.

The wood procurement GIS which was developed in this study was based on the criteria set forth by Tomlinson (1976). But, a continued perceived need to handle the data may not be present, as the primary purpose of this study was to evaluate a new approach to an ever present problem in wood procurement -- where to begin or continue the search for wood. Intuitively, the open market should produce a more uniform level of demand over an area of the size of the study region, but through the use of GIS, this was shown to not necessarily be true in the northwest region of Louisiana. This approach to wood procurement analysis could be used by government agencies that monitor forest inventories within their jurisdiction, and also by forest industry personnel. The demand data by wood-using location provided by wood procurement managers for this study would not be readily available to competitors, and would require additional review of public records and assumptions of homogeneity in larger procurement polygons than those used in this study.

In this study, several assumptions were made. The validity of these assumptions should be assessed in any future analysis of a regional wood procurement environment with a GIS. The first assumption was that the study area was a closed region with respect to the spatial pulpwood demand. The lack of interaction of neighboring wood procurement centers was assumed to facilitate the analysis. This is a restrictive assumption, but the problem of regional edge effects and neighboring competition is present in most spatial analyses.

The accuracy of pulpwood purchase volumes by the study respondents was assumed to be accurate. If sufficient time were available, total pulpwood volumes purchased by each respondent could be verified by a comparison to public timber tax records. In addition, the actual volumes purchased by the non-respondents could be determined.

A third assumption was homogeneity of forest attributes within a parish. The presence of built-up areas, farm and pasture land, and other non-forest areas was realized. An effort to segregate the forest land from the non-forest land was not attempted in this study, as it was a macro approach to the wood procurement problem. Revision of this assumption could be made in future studies based on the study objectives.

The interpretation of highway distance isolines as a realistic portrayal of procurement zones was assumed. This assumption was predicated on the large percentage of pulpwood purchases being transported through the highway network. The accuracy of this assumption could be examined by additional research of the transportation systems. An analysis of transportation distances and pulpwood volumes from the woods to the procurement center could be performed on a sample of wood procurement centers in the study region.

The final assumption was the retention of spatial pulpwood demand densities when wood concentration yards were relocated. Spatial demand density for the wood fiber resource is probably unique for each wood procurement center location. The demand distribution is a result of the wood procurement forester's efforts in conjunction with the surrounding spatial patterns of forest land ownership, growing stock, removals, and the transportation network. An assumption of a uniform distribution of pulpwood purchases at the new location could have been used, but, this might be any nearer to reality than maintaining the original spatial demand distribution. To produce a more realistic spatial demand distribution at the new location would require more detailed spatial data concerning the above mentioned attributes. Also, when a wood concentration yard was relocated, the spatial demand densities of the remaining woodyards were assumed to remain constant. This may not be necessarily be true, as these remaining woodyards may increase their level of pulpwood purchases to fill any voids that were created.

Future efforts in this area of study could include the expansion of the study region to include the influence of neighboring regional pulpmills and wood concentration yards, and also incorporating the entire procurement zones of respondents in the study region. Inclusion of a buffer strip of approximately 75 kilometers surrounding the study region would probably reduce the edge effect observed on low demand areas within the study region.

Another continuation of the approach used in this study would be to intensively analyze a smaller region, such as two or three parishes. Forest type data might be obtained from satellite imagery, and land ownership information could be obtained from public records. In addition to total delivered pulpwood costs, data concerning local stumpage and transportation costs might also be included. A more detailed wood concentration yard relocation analysis could then be performed.

The difficulty of using proprietary information to determine spatial pulpwood demand densities was realized as a possible deficiency in future analyses. An attempt should be made to utilize public information, such as severance tax receipts and ownership records, and also consulting foresters to obtain wood purchase data by procurement center. An analysis using these data could be compared to the present study; thus, the utility of an actual pulpwood procurement scenario could be assessed.

Additional work could also be accomplished in a GIS analysis of the hardwood resource for the entire state. Based on the volumes of hardwood growing stock and removals, the hardwood resource within the state of Louisiana is underutilized, and as such, the most likely regions for development could be evaluated with a GIS. Input data on a parish basis is readily available, and could be incorporated into a GIS. This may assist in attracting new hardwood industries to specific locations in the state of Louisiana.

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Appendix I.

WOOD PROCUREMENT QUESTIONNAIRE

A. Procurement Organization

1. Wood procurement can be defined as all activities directly related to the purchase or securing of wood fiber resources for resale or manufacture. Do you agree with this definition?
   - Yes
   - No

   If not, how would you reword it according to your perception of wood procurement.

2. How many employees by category do you have dedicated primarily to wood procurement activities? Do not include personnel involved directly in timber harvesting activities.

		Number
a.	Foresters	_______
b.	Technicians	_______
c.	Administrative	_______
d.	Management	_______
e.	Other (identify)	_______

3. What type of procurement structure do you use, and what percent of your raw material is supplied by each.

		Percent
a.	Contract	
	1. Wood dealer	_______
	2. Residue	_______
	3. Cutting contracts	_______
b.	Internal forestry staff	
	1. Purchase stumpage	_______
	2. Procure wood from controlled lands	_______
c.	Open market purchases (gate wood)	_______
d.	Other (specify)	_______
	Total	100

4. Do you purchase open market or "gate wood" at this location?
   a. Yes
   b. No

   If yes, would you provide the current delivered price by species.

	Delivered Price	Units
a. Pine	________	____
b. Hardwood	________	____
c. Other (identify)	________	____

5. If you use a wood concentration yard system, indicate the percent of wood supplied by each type.

	Percent
a. Independent dealer	____
b. Company owned and operated	____
c. Company owned / dealer operated	____
Total	100

6. If you purchase stumpage, what percent is harvested by:

	Percent
a. Contractor	____
b. Company crew	____
Total	100

7. On company controlled lands, what percent is harvested by:

	Percent
a. Contractor	____
b. Company crew	____
Total	100

B. Raw Material Requirements

8. Of your total wood purchased, what percent of the wood species below do you purchase.

	Percent
a. Pine	____
b. Soft Hardwoods	____
c. Hard Hardwoods	____
d. Mixed Hardwoods	____
Total	100

9. In determining the price that you pay for stumpage, rate each of the following timber tract factors on a scale of 1 to 10 (10 being most important).

	Value
Distance (woods to mill)	______
Access by existing roads	______
Tract Size	______
Total Tract Volume	______
Public Highway Quality	______
Terrain	______
Soil	______
Contract Provisions	______
Ownership	______

10. *Identify the wood products you purchase, and* annual volume requirements of each (indicate unit of measure)

		Volume	Units
a.	Pulpwood	______	____
b.	Logs (sawlogs, veneer, poles)	______	____
c.	Chips	______	____
d.	Other (wastepaper, shavings, sawdust, etc.)	______	____

11. Indicate by source the percent of the above products which you obtain from fee-simple or leased land holdings (internal), and purchase from other landowners (external)

		Pulpwood	Logs	Chips	Other
a.	Internal	____	____	____	____
b.	External	____	____	____	____
	Total	100	100	100	100

C. Pulpwood and Chip Procurement Activities. The following questions apply <u>only</u> to pulpwood and chip procurement.

12. What inbound transportation modes do you employ and percent of each?

			Percent
a.	Truck:	bobtail	______
		10 cd. trailer	______
		longwood	______
		chips	______
b.	Rail:	pulpwood	______
		chips	______
c.	Water		______
		Total	100

13. What percent of your wood supply comes from other states?

		Percent
a.	Texas	________
b.	Arkansas	________
c.	________	________
d.	________	________

14. What are the hauling distances from woods to first delivery point (in miles) by each means of transportation mode?

		Maximum	Minimum	Average
a.	Truck	________	________	________
b.	Rail	________	________	________
c.	Water	________	________	________

15. Do you trade raw materials with other companies to reduce transportation costs?
    a. Yes
    b. No

16. If you procure wood for a pulpmill and use a system employing intermediate delivery points, ie. wood concentration yards, what are the hauling distances from yard to pulpmill by each transportation mode?

		Maximum	Minimum	Average
a.	Truck	________	________	________
b.	Rail	________	________	________
c.	Water	________	________	________

Where are your concentration yards located? Use the back of this sheet if required.

Have you opened or closed any new woodyards within the past 3 years? If so, would you name them and give the locations.

Open:

Closed:

17. Do you provide freight allowances based on distance to wood producers?
    a. Yes
    b. No

If you allow a standard freight allowance by distance and you can provide the table, please do so.

18. Assume 8 equal procurement corridors (like spokes on a wheel) radiating from your location. Please provide on the following list the percent of wood procured from each of these corridors. Disregard state lines.

	Percent
Sec. 1 (NNE)	________
Sec. 2 (ENE)	________
Sec. 3 (ESE)	________
Sec. 4 (SSE)	________
Sec. 5 (SSW)	________
Sec. 6 (WSW)	________
Sec. 7 (WNW)	________
Sec. 8 (NNW)	________

19. Regardless of corridor direction, indicate your wood procurement percent from woods to mill within the following mileage zones.

Radius(miles)	Percent
< 25	________
26 to 50	________
51 to 75	________
76 to 100	________
>100	________

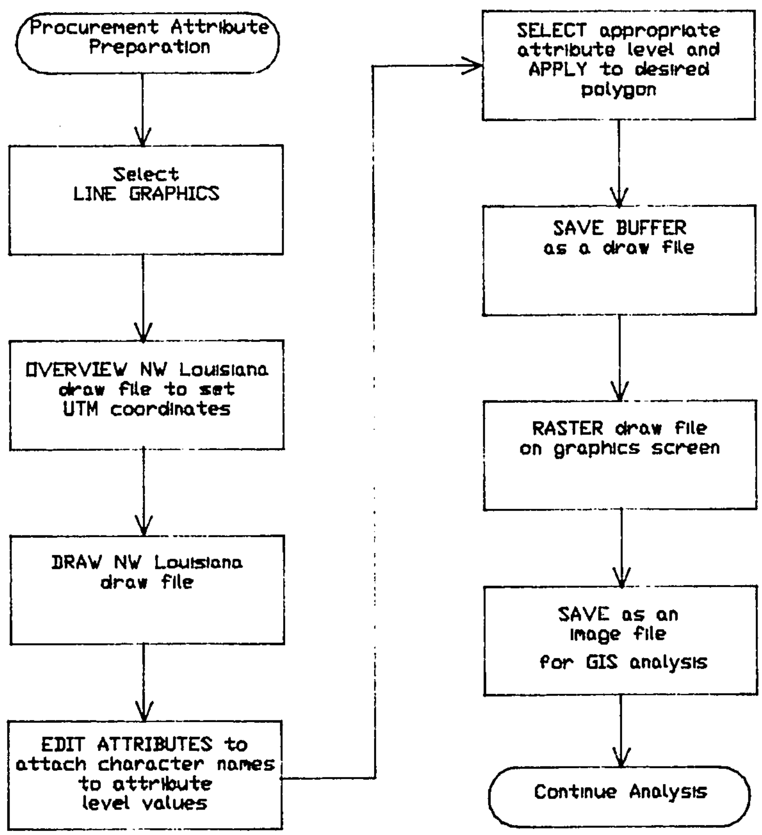
20. If you own or lease land and have a small-scale, general ownership map, can we have access to this map for this study.
    a. Yes
    b. No

____
Company Name

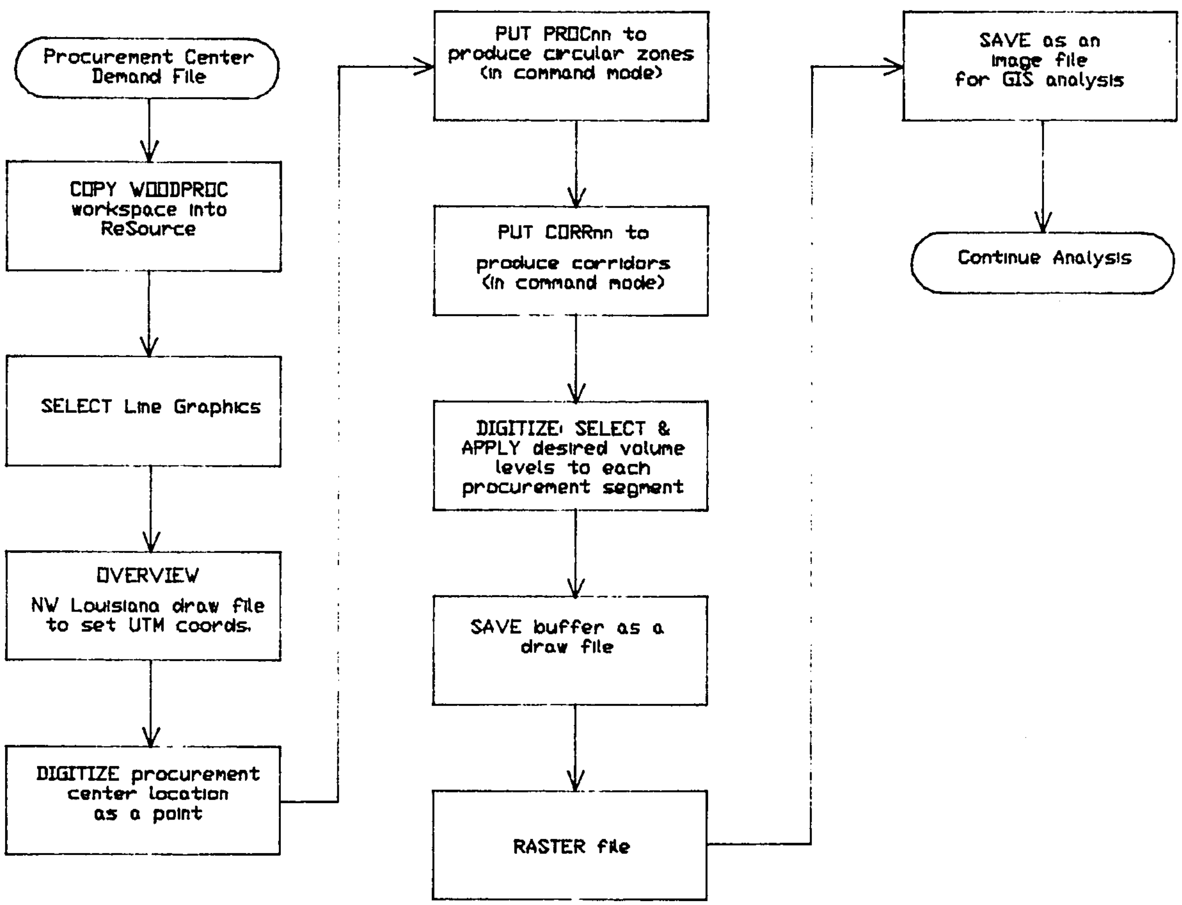
______________________________ ______________
Signature Date

Appendix II.

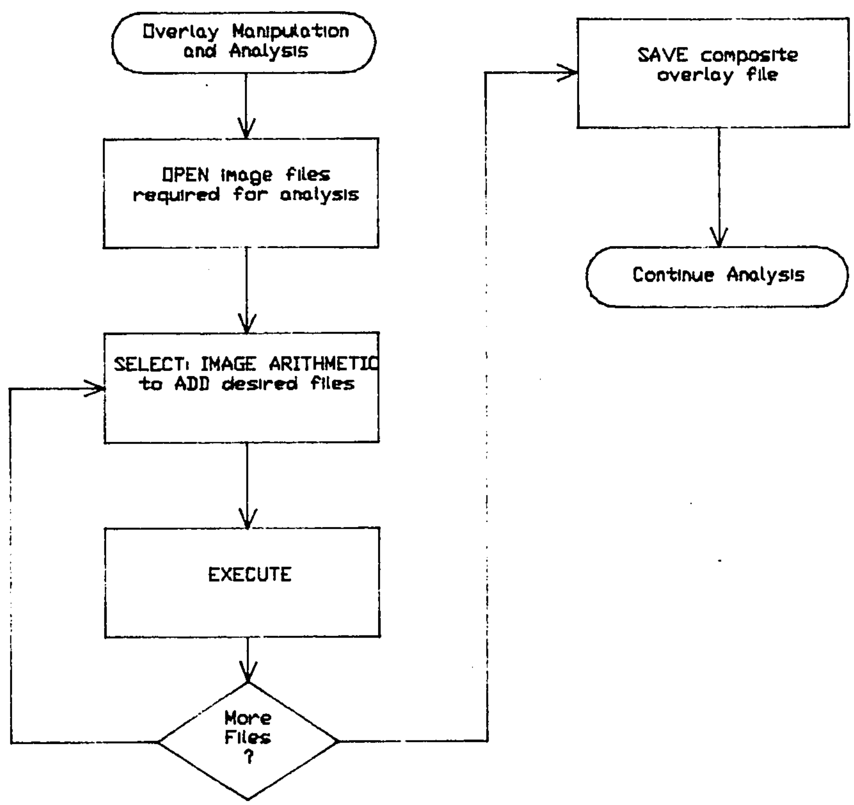
Procurement file production and overlay analysis and manipulation.



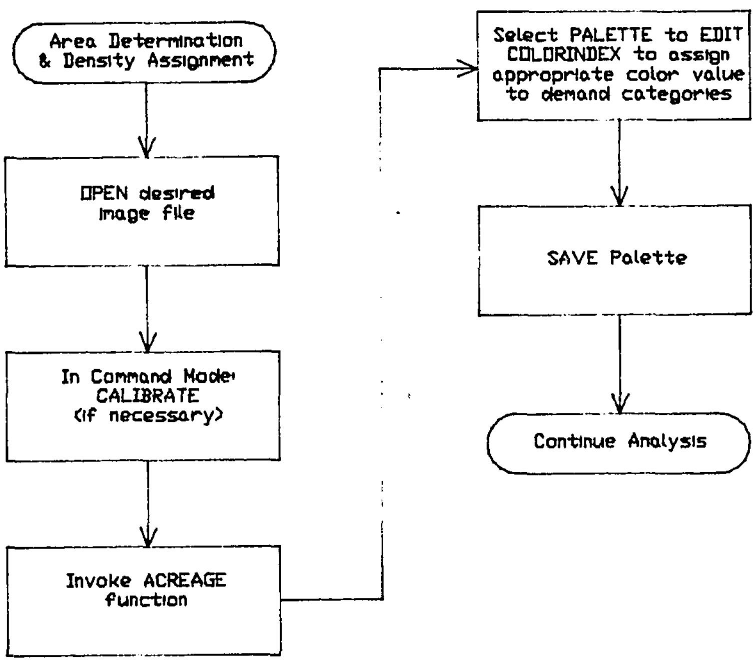
Production of procurement zones and corridors.



Overlay manipulation and analysis.



Area determination and procurement volume density assignment.



VITA

Richard William Brinker was born in Dubuque, Iowa on September 25, 1948. He attended elementary school in New Orleans, Louisiana, and graduated from Buena Park High School in Buena Park, California in June 1966. In June 1966, he entered Louisiana State University, graduating in May, 1970, with a Bachelor of Science degree in Forest Management.

He has worked as an industrial forester for 12 years in a variety of technical and managerial capacities. During this time he obtained a Master of Business Administration degree with a management emphasis from the University of Southern Mississippi in 1978. He is a member of the U.S. Army reserve. and currently holds the rank of Major, General Staff, USAR.

In 1983, he left the Masonite Corporation to continue his education as a PhD. student at Louisiana State University. He is majoring in Forestry and specializing in timber harvesting and wood procurement. He is now a candidate for a PhD. degree in May, 1988.

He is an active member in the Society of American Foresters, Xi Sigma Pi, Council on Forest Engineering, American Society of Photogrammetry and Remote Sensing, and the Forest Products Research Society.

He is married to the former Suzanne Reed, and they have one son, Jeffrey, aged 15.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Richard William Brinker

Major Field: Forestry

Title of Dissertation: Characterization of the Pulpwood Procurement Environment of Northwest Louisiana With A Geographic Information System

Approved:

Ben D. Jackson
Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

James E. Hotvedt

Robert B. Hamilton

Date of Examination:

January 13, 1988